

APPENDIX C

Engineering Design Criteria

- C.1 Foundations and Civil**
- C.2 Seismic and Structural**
- C.3 Mechanical**
- C.4 Control Systems**
- C.5 Electrical**

1 INTRODUCTION

The design, engineering, procurement, and construction activities on the project will be in accordance with various predetermined standards and project-specific practices. This appendix summarizes the civil engineering codes and standards, design criteria, and practices that will be used during design and construction. These criteria form the basis of the design for the foundations and civil systems of the project. More specific design information will be developed during the detailed design phase to support equipment procurement and construction specifications. It is not the intent of this appendix to present the detailed design information for each component and system, but rather to summarize the codes, standards, and general criteria that will be used.

Section 2 summarizes the applicable codes and standards, and Section 3 includes the general criteria for foundations, design loads, and site work.

2 DESIGN CODES AND STANDARDS

2.1 General Requirements

The design and specification of work will be in accordance with all applicable laws and regulations of the federal government, the State of California, and the applicable local codes and ordinances. Except where noted otherwise, the latest issue of all codes and standards, including addenda, in effect at the start of the project will be used, or as otherwise specified by governing agencies. The codes and standards, including all addenda, in effect at the time of purchase will be utilized for material and equipment procurement.

A summary of the codes and the standards to be used in the design and construction follows:

- Seismic standards and criteria will follow the California Building Code (CBC).
- Specifications for materials will follow the standard specifications of the American Society for Testing and Materials (ASTM) and the American National Standards Institute (ANSI), unless noted otherwise.
- Field and laboratory testing procedures for materials will follow ASTM standards.

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- Design and placement of structural concrete and reinforcing steel will be in accordance with the codes, guides and standards of the American Concrete Institute (ACI) and the Concrete Reinforcing Steel Institute (CRS1).
- Specifications for materials for roads will follow the State of California Department of Transportation Standard Specifications.
- Design and construction of roads will follow the American Association of State Highway and Transportation Officials (AASHTO), the State of California Department of Transportation standards, and California Fire Code (CFC).
- Design and construction of the sanitary sewer system will conform to the California Plumbing Code (CPC).
- Design and construction will conform to the federal and California Occupational Safety and Health Administration (OSHA and CAL-OSHA) requirements.

Other recognized standards will be used where required to serve as guidelines for the design fabrication, and construction.

2.2 Government Rules and Regulations

The following laws, ordinances, codes, and standards are applicable to the civil engineering design and construction. In cases where conflicts between cited codes (or standards) exist the requirements of the more stringent code will govern.

2.2.1 Federal

- Title 29, Code of Federal Regulations (CFR). Part 1910. Occupational Safety and Health Standards
- Title 29, CFR. Part 1926. National Safety and Health regulations for construction
- Walsh-Healy Public Contracts Act (Public Law [PL] 50-204.10)
- National Pollutant Discharge Elimination System (NPDES) (U.S. Environmental Protection Agency [EPA])

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2.2.2 State

- Business and Professions Code Section 6704, et seq.; Sections 6730 and 6736. Requires state registration to practice as a Civil Engineer or Structural Engineer in California.
- Labor Code Section 6500, et seq. requires a permit for construction of trenches or excavations 5 feet or deeper into which personnel have to descend. This also applies to construction or demolition of any building, structure, false work, or scaffolding that is more than three stories high or equivalent.
- Title 24, California Code of Regulations (CCR) Section 2-111, et seq.; Section 3-100, et seq.; Section 4-106, et seq.; Section 5-102, et seq.; Section 6-T8-769, et seq.; Section 6-T8-3233, et seq.; Section 6-T8-3270, et seq.; Section 6-T8-5138, et seq.; Section 6-T8-5465, et seq.; Section 6-T8-5531, et seq.; and Section 6-T8-5545, et seq. Adopts current edition of CBC as minimum legal building standards.
- State of California Department of Transportation, Standard Specifications
- Title 8, CCR Section 1500, et seq.; Section 2300, et seq.; and Section 3200, et seq. Describes general construction safety orders, industrial safety orders, and work safety requirements and procedures.
- Regulations of the following state agencies as applicable:
 - Department of Labor and Industry Regulations
 - Bureau of Fire Protection
 - Department of Public Health
 - Water and Power Resources
- Vehicle Code, Section 35780 et seq. requires a permit from Caltrans to transport heavy loads on state roads.

2.2.3 Local

County of Imperial – Planning & Building Department

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2.3 Industry Codes and Standards

**2.3.1 American Association of State Highway and Transportation
Officials (AASHTO)**

- A Policy on Geometric Design of Highways and Streets

2.3.2 American Concrete Institute (ACI)

ACI 117	Standard Specification for Tolerances for Concrete Construction and Materials
ACI 211.1	Standard Practice for Selecting Proportions of Normal, Heavyweight and Mass Concrete
ACI 301	Specifications for Structural Concrete for Buildings
ACI 302.1R	Guide for Concrete Floor and Slab Construction
ACI 304R	Guide for Measuring, Mixing, Transporting and Placing Concrete
ACI 305R	Hot Weather Concreting
ACI 306R	Cold Weather Concreting
ACI 308	Standard Practice for Curing Concrete
ACI 309R	Guide for Consolidation of Concrete
ACI 311.4R	Guide for Concrete Inspection
ACI 318	Building Code Requirements for Reinforced Concrete

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ACI 318.1 Building Code Requirements for Structural Plain Concrete

ACI 347R Guide to Formwork for Concrete

A.2.3.3 American Society for Testing and Materials (ASTM)

ASTM A82 Standard Specification for Steel Wire, Plain, for Concrete Reinforcement

ASTM A116 Standard Specification for Zinc-Coated (Galvanized) Steel Woven Wire Fence Fabric

ASTM A121 Standard Specification for Zinc-Coated (Galvanized) Steel Barbed Wire

ASTM A185 Standard Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement

ASTM A392 Standard Specification for Zinc-Coated Steel Chain-Link Fence Fabric

ASTM A615 Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement

ASTM C31 Standard Practice for Making and Curing Concrete Test Specimens in the Field

ASTM C33 Standard Specification for Concrete Aggregates

ASTM C39 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

ASTM C76 Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe

ASTM C94 Standard Specification for Ready-Mixed Concrete

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ASTM C109	Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2 in. or 50 mm Cube Specimens)
ASTM C136	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C138	Standard Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete
ASTM C143	Standard Test Method for Slump of Hydraulic Cement Concrete
ASTM C150	Standard Specification for Portland Concrete
ASTM C172	Standard Practice for Sampling Freshly Mixed Concrete
ASTM C231	Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C260	Standard Specification for Air-Entraining Admixtures for Concrete
ASTM C289	Standard Test Method for Potential Reactivity of Aggregates (Chemical Method)
ASTM C443	Standard Specification for Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets
ASTM C478	Standard Specification for Precast Reinforced Concrete Manhole Sections
ASTM C494	Standard Specification for Chemical Admixtures for Concrete
ASTM C586	Standard Test Method for Potential Alkali Reactivity of Carbonate Rocks for Concrete Aggregates (Rock Cylinder Method)
ASTM C618	Standard Specification for Coal Fly Ash and Raw or Calcinated Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete
ASTM C1064	Standard Test Method for Temperature of Freshly Mixed Portland Cement Concrete

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ASTM C1107	Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)
ASTM D422	Standard Test Method for Particle-Size Analysis of Soils
ASTM D698	Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft (600 kN-m/m))
ASTM D1556	Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method
ASTM D1752	Standard Specification for Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction
ASTM D2216	Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock
ASTM D2922	Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)
ASTM D3017	Standard Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth)
ASTM D3034	Standard Specification for Type PSM Poly Vinyl Chloride (PVC) Sewer Pipe and Fittings
ASTM D3740	Standard Practice for Evaluation of Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
ASTM D4318	Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM E329	Standard Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction

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2.3.4 Concrete Reinforcing Steel Institute (CRSI)

Manual of Standard Practice

2.3.5 International Association of Plumbing and Mechanical Officials

CPC California Plumbing Code

2.3.6 International Conference of Building Officials

CBC California Building Code

3 CIVIL DESIGN CRITERIA

3.1 Foundations

3.1.1 General

Geotechnical exploration, testing, and analysis determine the most suitable bearing methods for foundations. Criteria will be established to permit design of the most economical foundation that is compatible with the life expectancy and service of the structure. The results of the subsurface investigation, laboratory testing program, and geotechnical assessment for the proposed site are presented in Appendix J. Geotechnical Engineering Investigation. These results indicate that the facility can be constructed at the proposed location.

3.1.2 Foundation Design Criteria

Allowable settlements for all foundations (based on predicted elastic or short-term, and consolidation or long-term settlements) will be limited as follows:

- Total settlement: 3 inches
- Differential settlement: 1 1/2 inches between adjacent foundations

Foundations for all critical structures and equipment will be supported on reinforced concrete foundations bearing directly on a compacted structural fill foundation support system. Noncritical or lightly loaded structures and equipment will be founded on individual spread footings. The design of reinforced concrete foundations will satisfy the requirements of ACI 318.

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Shallow footings will have a minimum width of 2 feet for square footings, and a minimum width of 18 inches for continuous strip footings. The bottom of footings will be located at a minimum of 24 inches below finished grade.

Detailed foundation design criteria, including allowable bearing pressures, will be developed based on the results of subsurface investigations, see Appendix J. Allowable bearing pressures will include a safety factor of at least 2 against bearing failures.

3.1.3 Equipment Foundations

Each piece of equipment will be supplied with a reinforced concrete foundation suitable to its operation. Where the equipment could induce excessive vibration, the foundation will be provided with adequate mass to dampen vibratory motions. Special consideration will be given to vibration and stiffness criteria where specified by an equipment manufacturer. Equipment located within an enclosed building with a grade slab will generally be placed on a concrete pad that is raised above the grade slab to keep the equipment off the floor surface.

Minimum temperature and shrinkage reinforcing steel will be provided for equipment foundations unless additional reinforcement is required by design. Anchor bolts designed to develop their yield strength will be provided for critical equipment. For noncritical or lightly loaded equipment, concrete expansion anchors may be utilized to secure equipment to foundations.

3.1.4 Rotating Equipment Foundations

Dynamic behavior will be considered in the design of foundations subjected to significant rotating equipment loads such as foundations for the combustion turbines, steam turbines, and the boiler feedwater pumps. A dynamic analysis will be performed to determine the natural frequencies and dynamic responses of the foundation. To account for soil and structure interaction, geotechnical data will be used to determine the soil stiffnesses and damping coefficients used in the dynamic analysis.

Dynamic responses will satisfy the equipment manufacturer's criteria and/or industry standards in terms of maximum velocity/displacement amplitudes that are considered acceptable for machine and human tolerances. To avoid resonance during machine operation, the resonant frequency of the foundation will typically be less than 80 percent or greater than 120 percent of the machine operating speed.

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3.2 Design Loads

3.2.1 General

Design loads for structures and equipment foundations are discussed in Appendix B. Design loads for pavements and buried items will be determined according to the criteria described below, unless the applicable building code or local conditions require more severe design conditions.

3.2.2 Wheel Loads

Loads excited on roadway pavements, buried piping, electrical duct banks, and culverts will be reviewed and selected prior to design of the underlying items. As a minimum, these items will be designed for H20 loadings in accordance with AASHTO Standard Specifications. Loadings exceeding the H20 loadings will be considered where found applicable during the detailed design phase.

A surcharge load of 250 psf will be applied to plant structures accessible to truck traffic.

3.3 Site

3.3.1 Site Arrangement

The site arrangement will conform to all applicable laws, regulations, and environmental standards. The principal elements to be considered in selection of the site arrangement are the physical space requirements and relationships dictated by each of the major plant systems, and the constraints imposed by the physical size and existing topography of the site. Distances from the main plant to various systems will be minimized for economy. However, adequate clearance between various plant systems will be provided as needed for construction, operations, maintenance, and fire protection. The plant will be configured to minimize construction costs and visual impacts while remaining operationally effective. Utility interconnections will be optimized.

3.3.2 Site Preparation

Site preparation will consist of clearing and grubbing, the excavation of soils to design grade, and the preparation of fill slopes and embankments designed in such a fashion as to be stable and capable of carrying anticipated loads from either equipment or structures.

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Root mats or stumps, trees if any, will be removed to a depth of not less than 1.5 feet below existing grade, and holes will be refilled with material suitable for embankment and compacted. Materials from clearing and grubbing operations will be removed from the site and stockpiled on an adjoining parcel for reuse by the owner.

3.3.3 Earthwork

Earthwork requirements are based on the results of the subsurface investigation in Appendix J, *Geotechnical Study, Proposed Black Rock Units 1, 2, & 3, Single Flash Geothermal Plant, Calipatria, California*, by Fugro West, Inc. (December 2008).

Shallow foundations built on controlled compacted structural fill and natural dense granular soils are expected to provide adequate bearing pressures. Estimated total static settlements and estimated liquefaction induced settlements are summarized in the Geotechnical Study. It is anticipated that cement treated soil will be imported from an offsite location and compacted. This fill will be placed under all roadways and equipment areas. It will also be installed to support well drilling equipment.

Excavation. Excavation work will consist of the removal, storage, and/or disposal of earth, sand, gravel, vegetation, organic matter, loose rock, boulders, and debris to the lines and grades necessary for construction.

Materials suitable for backfill will be stored in stockpiles at designated locations using proper erosion protection methods. Stockpiles of varying material types shall be separated to ensure that no intermixing occurs. Other excess noncontaminated material will be removed from the site and disposed of at a location designated by the owner. Disposal of contaminated material if encountered during excavation will comply with all applicable federal, state, and local regulations.

Confined temporary excavations will be sloped or braced to prevent cave-ins during construction. All excavation and trenching operations will comply with local, state, and federal OSHA regulations.

Based on soil borings performed for the subsurface investigation, the groundwater averages were about five feet below existing grades at time of the geotechnical study.

Grading and Embankments. Graded areas will be smooth, compacted, free from irregular surface changes, and sloped to drain.

Final earth grade adjacent to buildings will be at least 6 inches below finished floor slab and

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will be sloped away from the building to maintain proper drainage.

Cut and fill slopes for permanent embankments will be designed to withstand horizontal ground accelerations for seismic design criteria as defined by site specific geotech investigation, this will likely result in flat slopes. Geogrid reinforcement for fill slopes and soil nailing for cut slopes may be used for steep slopes requiring soil reinforcement to resist seismic loading. Slopes for embankments will be no steeper than 2:1 (horizontal: vertical). The grading plan may require the use of retaining walls. These will also be designed for seismic design criteria as defined by site specific geotechnical investigation.

Backfilling and Compaction. Areas to be backfilled will be prepared by removing unsuitable material and rocks. The bottom of an excavation will be examined for loose or soft areas. Such areas will be excavated fully and backfilled with compacted fill. To provide material capable of supporting equipment and construction activities, it might be necessary to add Portland cement to imported fill material in accordance with the Geotechnical Investigation and recommendations or a combination of geotextile, crushed rock and filter fabric.

Backfilling will be done in layers of uniform, specified thickness. Soil in each layer will be properly moistened to facilitate compaction to achieve the specified density. In order to verify compaction, representative field density and moisture-content tests will be taken during compaction.

Structural fill supporting foundations, roads, parking areas, etc., will be compacted to at least 95 percent of the maximum dry density as determined by ASTM D698. Embankments, dikes, bedding for buried piping, and backfill surrounding structures will be compacted to a minimum of 90 percent of the maximum dry density. General backfill placed in remote and/or unsurfaced areas will be compacted to at least 85 percent of the maximum dry density.

The subgrade (original ground), subbases, and base courses of roads will be prepared and compacted in accordance with California Department of Transportation (Caltrans) requirements or as specified by geotechnical investigation. Testing will be in accordance with ASTM and Caltrans standards.

3.3.4 Berm Construction

The existing berm surrounding the site must be raised to an elevation of at least 220.0 feet below sea level to protect the site from flooding. This must be accomplished by not infringing on surrounding properties. To accomplish this it is anticipated that the roads surrounding the property will shift inward toward the site and all slopes will also shift inward

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toward the site. All imported soil to raise the berms should be a mixture of available soil mixed with Portland cement to provide suitable material that is structurally sound and that will provide the necessary flood protection.

3.3.5 Site Drainage

The site drainage system will be designed to comply with all applicable federal, state, and local regulations. Onsite drainage will be accomplished by gravity flow, whenever possible. The surface drainage system will consist of mild slopes and open channels. The ground floor elevation of buildings and structures will be maintained at a minimum of 6 inches above the finished grade. The graded areas away from structures will be at a minimum slope of 1 percent.

Design of the site drainage facilities will be performed in accordance with state and local governmental requirements. Drainage facilities will be designed for the flow resulting from a 10 year, 24 hour rainfall. They will also be designed to prevent flooding of permanent plant facilities and overflow of plant roads during a 50 year, 24-hour storm. The flow of storm water within the site will be designed to generally follow the existing flow.

Runoff from possible oil and chemical contamination areas, such as the lube oil storage area, transformer areas, and chemical storage areas, will be contained and routed through an oil/water separator.

Ditches. Open channels and ditches generally will be trapezoidal in cross section, of sufficient width to facilitate cleaning, and mildly sloping so that erosion of the ditch bottom due to high flow velocities is minimized. Side slopes on ditches will be approximately 2:1 (horizontal: vertical) unless soil conditions dictate otherwise. The slope of the ditch bottom will generally be 1 percent, with a minimum slope of 0.5 percent. In areas where space is limited and design flow rates are small, ditches having a V-shaped cross section may be provided.

Ditches will be designed to carry the 10 year, 24-hour rainfall runoff with nonerosive velocities.

Culverts. Drainage culverts will be provided for passage of surface drainage under roads or embankments. Culverts will be constructed of reinforced concrete or corrugated metal pipe.

Culverts will be designed to convey the 10 year, 24-hour rainfall peak runoff flow without producing a headwater elevation above the pipe soffit. Cover provided under roads will be as

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required for wheel loads in accordance with Section 3.2.2. Minimum cover will be 12 inches.

Erosion and Sedimentation Control. The proposed site development will alter the land areas of the site. Existing vegetation will be removed during site preparation operations. This will be followed by the earthwork activities required for construction of specific facilities. Final finish grading will begin when all other earthwork operations are complete.

Erosion and sedimentation control will be provided to retain sediment on site and prevent violations of water quality standards.

Permanent erosion and sedimentation control measures within the plant site will include the runoff collection system (ditches, inlets, culverts, drainage piping) and surfaced traffic and work areas. Final grading will include aggregate surfacing of the entire power block areas except for paved roadway areas. These measures will minimize the possibility of any appreciable erosion, and the resulting sedimentation, from occurring on the site. Temporary erosion and sediment control measures which comply with the state and local requirements will be utilized during the construction phase.

3.3.6 Roads

Access to the plant site will be from Boyle Road. Access within the plant site will be provided by the asphalt paved loop road that encircles the power block and major equipment in the resource production facility. The road will be a minimum of 20 feet wide with a 2 foot shoulder on each side.

Unless otherwise required by Governing agencies, all other plant roads will generally be a minimum of 20 feet in width with an asphaltic cement paved surface. The permanent parking area adjacent to the administration/control building will be paved with asphalt.

The longitudinal slope of roads will not exceed 7 percent. The crown or transverse slope will be 2 percent. The minimum radius to the inside edge of roads (pavement or gravel) will be 20 feet.

3.3.7 Fencing and Security

Chain-link security fencing will be provided around the facility site, substation, and other areas requiring controlled access. Fencing heights will be in accordance with applicable codes and regulatory requirements. Controlled access gates will be located at the entrances to secured areas.

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3.3.8 Sanitary Waste System

The sanitary waste system design will conform to the Imperial County regulations and California Plumbing Code. Sanitary wastes will be discharged to a septic tank/holding tank for periodic pumping and disposal at an approved disposal site.

The total quantity of flow used in sizing the sanitary waste system will be calculated based on the total equivalent fixture units provided. Pipe will be sloped to provide a 2.5 fps minimum velocity, half full. Minimum slope for main sewer pipe will be 1.0 percent.

The minimum diameter of sewer pipe will be 4 inches. Manholes will be provided at a maximum spacing of 300 ft. and at each change in direction greater than 45°.

3.3.9 Spill Protection

Spill containment measures will be provided for chemical storage tanks and chemical additive/lube oil skid areas. All other chemical storage tanks will be provided with a containment structure with a volume equal to at least 100 percent of the largest tank capacity plus 6" of freeboard. In addition, all outdoor containment structures will have a volume equal to at least the capacity of the tank plus the volume of rainfall from a 100 year, 24 hour storm additional volume from deluge systems or other fire protection measures shall also be considered. Concrete curbs will be provided for chemical additive/lube oil skid areas. Where required for protection of the containment structure, appropriate surface coatings will be provided.

3.4 Geotechnical Investigation

The Geotechnical Engineering Investigation for the project is included as Appendix J.

1 INTRODUCTION

The project design, engineering, procurement, and construction activities will be in accordance with various predetermined standards and project-specific practices. This appendix summarizes the structural and seismic engineering codes and standards, design criteria, and practices that will be used during design and construction. These criteria form the basis for the project structural design work. More specific design information will be developed during detailed design to support equipment procurement and construction specifications. It is not the intent of this appendix to present the detailed design information for each component and system, but rather to summarize the codes, standards, and general criteria that will be used.

Section 2 summarizes the applicable codes and standards, and Section 3 includes the general criteria for natural phenomena, design loads, materials, seismic design, and architecture. Section 4 describes the structural design methodology for structures and equipment. Section 5 addresses project hazard mitigation.

2 DESIGN CODES AND STANDARDS

2.1 General Requirements

Work will be designed and specified in accordance with applicable laws and regulations of the federal government and the State of California and applicable local codes and ordinances. Except where noted otherwise, the latest issue of codes and standards, including addenda, in effect at the start of the project will be used. The codes and standards, including addenda, in effect at the time of purchase will be used for material and equipment procurement.

A summary of the codes and the standards to be used in design and construction follows:

- Seismic standards and criteria will follow the California Building Code (CBC).
- Specifications for materials will follow the standard specifications of the American Society for Testing and Materials (ASTM) and the American National Standards Institute (ANSI), unless noted otherwise.
- Field and laboratory testing procedures for materials will follow ASTM standards.

- Structural concrete and reinforcing steel will be designed and placed in accordance with the codes, guides, and standards of the American Concrete Institute (ACI) and the Concrete Reinforcing Steel Institute (CRSI).
- Structural steel will be designed, fabricated, and erected in accordance with the American Institute of Steel Construction (AISC) Manual of Steel Construction - Allowable Stress Design.
- Steel components for metal wall panels and roof decking will conform to the American Iron and Steel Institute (AISI) Specification for the Design of Cold-Formed Steel Structural Members.
- Welding procedures and qualifications for welders will follow the recommended practices and codes of the American Welding Society (AWS).
- Metal surfaces for coating systems will be prepared following the specifications and standard practices of the Steel Structures Painting Council (SSPC) and the specific instructions of the coatings manufacturer.
- Masonry materials will be designed and erected in accordance with the ACI Building Code Requirements for Masonry Structures.
- Roof covering design will comply with the requirements of the National Fire Protection Association (NFPA) and Factory Mutual (FM).
- Design and construction will conform to federal and California Occupational Safety and Health Administration (OSHA and CAL-OSHA) requirements.

Other recognized standards will be used where required to serve as guidelines for design, fabrication, and construction. When no other code or standard governs, the California Building Code (CBC), 2007 Edition will govern.

2.2 Government Rules and Regulations

The following laws, ordinances, codes, and standards are applicable to structural design and construction. In cases where conflicts between cited codes (or standards) exist, the requirements of the more stringent code will govern. The sections in the California Building Code (CBC) have been quoted throughout this document as reference. These sections are based on the 2007 editions of CBC. However, the latest edition of CBC at the start of the project will apply to the engineering design.

2.2.1 Federal

- Title 29, Code of Federal Regulations (CFR), Part 1910, Occupational Safety and Health Standards.
- Title 29, CFR, Part 1926, National Safety and Health regulations for construction.
- Walsh-Healy Public Contracts Act (Public Law [PL] 50-204.10).

2.2.2 State

- Business and Professions Code Section 6704, et seq.; Sections 6730 and 6736. Requires state registration to practice as a Civil Engineer or Structural Engineer in California.
- Labor Code Section 6500, et seq. Requires a permit for construction of trenches or excavations 5 feet or deeper into which personnel have to descend. This also applies to construction or demolition of any building, structure, false work, or scaffolding that is more than three stories high or equivalent.
- Title 24, California Code of Regulations (CCR) Section 2-111, et seq.; Section 3-100, et seq.; Section 4-106, et seq.; Section 5-102, et seq.; Section 6-T8-769, et seq.; Section 6-18-3233, et seq.; Section 6-T8-3270, et seq.; Section 6-T8-5138, et seq.; Section 6-T8-5465, et seq.; Section 6-T8-5531, et seq.; and Section 6-T8-5545, et seq. Adopts current edition of CBC as minimum legal building standards.
- Title 8, CCR Section 1500, et seq.; Section 2300, et seq.; and Section 3200, et seq. Describes general construction safety orders, industrial safety orders, and work safety requirements and procedures.
- Regulations of the following state agencies as applicable:
 - Department of Labor and Industry Regulations
 - Bureau of Fire Protection
 - Department of Public Health
 - Water and Power Resources

2.2.3 Local

- County of Imperial – Planning and Building Department

2.3 Industry Codes and Standards

2.3.1 American Concrete Institute (ACI)

ACI 117	Standard Specification for Tolerances for Concrete Construction and Materials
ACI 211.1	Standard Practice for Selecting Proportions of Normal, Heavyweight, and Mass Concrete
ACI 301	Specifications for Structural Concrete for Buildings
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ACI 304R	Guide for Measuring, Mixing, Transporting, and Placing Concrete
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ACI 318.1	Building Code Requirements for Structural Plain Concrete
ACI 347R	Guide to Formwork for Concrete
ACI 530	Building Code Requirements for Masonry Structures
ACI 530.1	Specifications for Masonry Structures

2.3.2 American Institute of Steel Construction (AISC)

Code of Standard Practice for Steel Buildings and Bridges

Manual of Steel Construction - Allowable Stress Design

Specification for Structural Steel Buildings - Allowable Stress Design and Plastic Design

Allowable Stress Design Specification for Structural Joints Using ASTM A325 or A490 Bolts

2.3.3 American Iron and Steel Institute (AISI)

Specification for the Design of Cold-Formed Steel Structural Members

2.3.4 American Society for Testing and Materials (ASTM)

ASTM A36	Standard Specification for Structural Steel
ASTM A53	Standard Specification for Pipe. Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A82	Stranded Specification for Steel Wire, Plain, For Concrete Reinforcement
ASTM A106	Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service
ASTM A108	Standard Specification for Steel Bars, Carbon, Cold Finished, Standard Quality
ASTM A123	Standard Specification for Zinc (Hot-Dip Galvanized) coatings on Iron and Steel Products
ASTM A153	Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel hardware
ASTM A185	Standard Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement
ASTM A240	Standard Specification for Heat-resisting Chromium and Chromium-Nickel Stainless Steel plate, Sheet and Strip for Pressure Vessels

ASTM A276	Standard Specification for Stainless and Heat-Resisting Steel Bars and Shapes
ASTM A307	Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength
ASTM A446	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) by Hot-Dip Process, Structural (Physical) Quality
ASTM A500	Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
ASTM A501	Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing
ASTM A615	Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
ASTM B695	Standard Specification for Coatings of Zinc mechanically Deposited on Iron and Steel
ASTM C31	Standard Practice for Making and Curing Concrete Test Specimens in the Field
ASTM C33	Standard Specification for Concrete Aggregates
ASTM C39	Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C90	Standard Specification for Load-Bearing Concrete Masonry Units
ASTM C94	Standard Specification for Ready-Mixed Concrete
ASTM C109	Standard Test method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens)
ASTM C129	Standard Specification for Non-Load Bearing Concrete Masonry Units
ASTM C136	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C138	Standard Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete

ASTM C143	Standard Test Method for Slump of Hydraulic Cement Concrete
ASTM C150	Standard Specification for Portland Cement
ASTM C172	Standard Practice for Sampling Freshly Mixed Concrete
ASTM C231	Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C260	Standard Specification for Air-Entraining Admixtures for Concrete
ASTM C270	Standard Specification for Mortar for Unit Masonry
ASTM C289	Standard Test Method for Potential Reactivity of Aggregates (Chemical Method)
ASTM C494	Standard Specification for Chemical Admixtures for Concrete
ASTM C586	Standard Test Method for Potential Alkali Reactivity of Carbonate Rocks for Concrete Aggregates (Rock Cylinder Method)
ASTM C618	Standard Specification for Coal Fly Ash and Raw or Calcinated natural Pozzolan for use as a Mineral Admixture in Portland Cement Concrete
ASTM C1064	Standard Test method for Temperature of Freshly Mixed Portland Cement Concrete
ASTM C1107	Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)
ASTM D1752	Standard Specification for Performed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction
ASTM E329	Standard Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction

2.3.5 American Society of Mechanical Engineers (ASME)

Boiler and Pressure Vessel Code, Section VIII, Rules for Construction of Pressure Vessels, Division 2 - Alternative Rules

ASME/ STS-1, Steel Stacks

2.3.6 American Society of Civil Engineers (ASCE)

ASCE 7 Minimum Design Loads for Buildings and Other Structures

2.3.7 American Water Works Association (AWWA)

AWWA D100 Welded Steel Tanks for Water Storage

2.3.8 American Welding Society (AWS)

AWS D1.1 Structural Welding Code - Steel

AWS D1.4 Structural Welding Code - Reinforcing

Steel

2.3.9 California Energy Commission

Recommended Seismic Design Criteria for Non-Nuclear Generating Facilities in California

8.2.3.10 Concrete Reinforcing Steel Institute (CRSI)

Manual of Standard Practice

2.3.11 International Conference of Building Officials

CBC California Building Code

2.3.12 Metal Building Manufacturers Association (MBMA)

Low Rise Building Systems Manual

2.3.13 National Fire Protection Association (NFPA)

NFPA 22	Standard for Water Tanks for Private Fire Protection
NFPA 24	Standard for the Installation of Private Fire Service Mains and Their Appurtenances
NFPA 80	Standard for Fire Doors and Fire Windows
NFPA 850	Recommended Practice for Fire Protection for Electric Generating Plants

2.3.14 Steel Structures Painting Council (SSPC)

Steel Structures Painting Manual, Volume 2, Systems and Specifications

3 STRUCTURAL DESIGN CRITERIA

3.1 Natural Phenomena

The design criteria based on natural phenomena are discussed in this section. The climatological data listed were retrieved from isopluvials for 100 year, 24 hour precipitation for southern half of California, prepared by U.S. Department of Commerce. National Oceanic & Atmospheric Administration, National Weather Service Office of Hydrology. The detail design will be based on the latest available data at the start of the project.

3.1.1 Rainfall

100 year, 24 hour precipitation: 2.5 inches

3.1.2 Wind Speed

The basic wind speed for design purposes will be 85 mph based on Figure 6-1 of ASCE 7-05 for a 50-year recurrence interval, or higher if required by the local authority having jurisdiction. The basic wind speed will be used to determine the wind loads on structures as discussed in Section 3.2.3.

3.1.3 Temperature

Maximum: 122 F
Minimum: 2 F

Annual Average: 72 F

3.1.4 Relative Humidity

The average relative humidity is 40 percent.

3.1.5 Seismicity

The plant site is located in an area designated as Site Class F due to the liquefaction potential that has been estimated at the site, as determined from Chapter 16 of the CBC. However, Site Class D is appropriate for use if soil improvement measures will be implemented beneath proposed structures to mitigate the liquefaction potential. The following table summarizes the seismic design parameters to be used in general accordance with Section 1613 of CBC for Site Class D.

Table 1. Summary of 2007 CBC Seismic Design Parameters for Site Class D

Parameter	Value
Latitude	33.1657
Longitude	-115.6272
Occupancy Category (Table 1604.5)	III
S_S	1.5 ¹
S_1	0.6 ₁
Seismic Design Category (Section 1613.5.6)	D
Soil Profile (per Table 1613.5.2)	D ²
F_a	1.0
F_v	1.5
S_{MS}	1.5
S_{M1}	0.9
S_{DS}	1.0
S_{D1}	0.6
Notes: 1) Coefficients estimated using the USGS calculator available at http://earthquake.usgs.gov/research/hazmaps/design/index.php for cited latitude and longitude and Site Class. 2) Site Class D is appropriate only if liquefaction mitigation measures are implemented. Otherwise, Site Class F is appropriate and a site-specific evaluation is required per CBC 2007, Section 1613.5.5.1.	

CBC Seismic Design Requirements for Site Class F

A preliminary evaluation using a range of expected ground motion parameters (peak ground accelerations and earthquake magnitudes) indicates relatively significant liquefaction potential at the site. For expected ground motions corresponding to return periods between about 100 to 500 years, approximately 40 feet of the upper 50 to 60 feet of soil at the site has the potential to liquefy.

As stated above, due to the liquefaction potential, the site class for seismic design is Site Class F. Section 1613.5.5.1 of the CBC 2007 and Section 11.4.7 of the ASCE 7-05 indicate that for Site Class F, a site-specific response analysis shall be performed, i.e., seismic design parameters provided in the CBC are not sufficient to develop the design response spectra. Therefore, the seismic design parameter coefficients, such as those provided in Table 1 for Site Class D, cannot be directly obtained from the CBC for Site Class F.

An exception to the site response analysis requirement for Site Class F is allowed for structures with a structural period less than or equal to 0.5 seconds (Section 20.3.1 of the ASCE 7-05). For structures having a structural period of less than or equal to 0.5 seconds, the seismic coefficients estimated for Site Class D can be used to develop the design response spectra.

For structures having a structural period greater than 0.5 seconds that are built on the site with no mitigation against liquefaction, a site-specific response analysis must be performed to develop a CBC-based design response spectra.

3.1.6 Snow

The plant site is located in a zero ground snow load area.

3.2 Design Loads

3.2.1 Dead Loads

Dead loads include the weight of all components forming the permanent parts of structures and all permanent equipment. The dead load of permanent plant equipment will be based on actual equipment weights. For major equipment, structural members and foundations will be specifically located and designed to carry the equipment load into the structural system. For equipment weighing less than the uniform live load, the structural system will be designed for the uniform live load.

The contents of tanks and bins at full operating capacity will be considered as dead loads. The contents of tanks and bins will not be considered effective in resisting uplift due to wind forces but will be considered effective for seismic forces.

A uniform load of 50 psf will be used to account for piping and cable trays, except in

administration building areas, and will be carried to the columns and foundations as dead loads. Uniform piping and cable tray loads will not be considered effective in resisting uplift due to wind forces, but will be considered effective for seismic forces. Additional piping loads will be considered in the design of areas with heavy piping concentrations. After critical and/or heavy piping hanger loads and locations are established, the supporting members will be reviewed for structural adequacy.

For piperacks, the weight of piping and cable trays will be treated as live load.

3.2.2 Live Loads

Live loads are the loads superimposed by the use and occupancy of the building or structure. They do not include wind loads, snow loads, or seismic loads.

Uniformly distributed live loads are specified to provide for movable and transitory loads, such as the weight of people, office furniture and partitions, portable equipment and tools, and other nonpermanent materials. These uniform live loads will not be applied to floor areas permanently occupied by equipment, with no access beneath. Uniform live loads for equipment lay-down areas will be based on the actual weight and size of the equipment and parts that may be temporarily placed on floors during dismantling, maintenance, installation, or removal.

The design live loads will be as follows:

- **Ground Floor (Grade Slab)** - A uniform load of 250 psf, nonpermanent equipment weights, storage weights, or lay-down weights, whichever is greater, will be used.
- **Grating Floors, Platforms, Walkways, and Stairs** - A uniform live load of 100 psf will be used. In addition, a concentrated load of 2 kips will be applied concurrently to the supporting beams to maximize stresses in the members, but the reactions from the concentrated load will not be carried to columns. Maximum deflection of the grating will be limited to 1/200 of the span.
- **Elevated Concrete Slabs** - A uniform load of 100 psf, nonpermanent equipment weights, storage weights, or lay-down weights, whichever is greater, will be used.

Elevated concrete slabs will be designed to support either the prescribed live load or a single concentrated load of 2 kips, whichever produces the greater stresses. The concentrated load will be treated as uniformly distributed load acting over an area of 2.5 square feet and will be located to produce the maximum stress conditions in the slab. Metal decking for concrete slabs will be designed for a load during construction equal to the weight of concrete plus 50 psf (no increase in allowable stress).

- **Roof** - Roof areas will be designed for a minimum live load of 20 psf. Ponding loading effect due to roof deck and framing deflections will be investigated in accordance with Section K2 of the AISC Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design.
- **Piperacks** - A minimum uniform load of 100 psf will be used for each level of the piperacks, except that where piping and cable tray loads exceed 100 psf, the actual loads will be used. In addition, a concentrated load of 5 kips will be applied concurrently to the supporting beams to maximize stresses in the members, but the reactions from the concentrated loads will not be carried to columns.
- **Truck Loads** - A surcharge load of 250 psf will be applied to plant structures accessible to truck traffic.

Road pavements, underground piping, conduits, sumps, and foundations subject to truck traffic will be designed for wheel loadings in accordance with Appendix C.1, Section 3.2.2.

- **Thermal Forces** - Thermal forces caused by thermal expansion of equipment and piping under all operating conditions will be considered.
- **Dynamic Loads** - Dynamic loads will be considered and applied in accordance with the manufacturer's criteria/recommendations and industry standards.

3.2.3 Wind Loads

Wind loads for structures and their components will be determined in accordance with ASCE 7, using a basic wind speed of 85 mph at 33 feet above grade. Occupancy Category III and an Importance Factor of 1.15 will be used. Exposure category C should be used, unless local site conditions require use of exposure category D.

3.2.4 Seismic Loads

Seismic loads will be determined in accordance with the requirements specified in Section 3.4.

3.2.5 Other Loads

Other expected loads required to predict the structural response of structures will be considered where appropriate (i.e., water hammer, test loads, etc.).

3.2.6 Load Combinations

Applicable code prescribed load combinations will be considered in the design of structures. As a minimum, the following load combinations will be considered, where allowable stress design is used:

- Dead load
- Dead load + live load + operating loads
- Dead load + live load + operating loads + 1.3 wind load
- Dead load + live load + operating loads + seismic /1.4
- Dead load + construction loads
- Dead load + live load + emergency loads
- $\frac{2}{3}$ Dead load + wind load
- 0.9 Dead load + seismic/1.4 load

Operating loads include all loads associated with normal operation of the equipment (e.g., temperature and pressure loads, piping loads, normal torque loads, impact loads, etc.).

3.2.7 Strength Requirements

Each load combination will not exceed the stress or strength levels permitted by the appropriate code for that combination.

3.2.7.1 Concrete Structures. The required strength (U) of concrete structures will be at least equal to the following, or as required by 2007 CBC Section 1605.2:

- $U = 1.4 \text{ Dead}$
- $U = 1.2 \text{ Dead} + 1.6(\text{Live} + \text{Earth}) + 0.5 \text{ Roof Live}$
- $U = 1.2 \text{ Dead} + 1.6 \text{ Roof Live} + (0.5 \text{ Live or } 0.8 \text{ Wind})$
- $U = 1.2 \text{ Dead} + 1.6 \text{ Wind} + 0.5 \text{ Live} + 0.5 \text{ Roof Live}$
- $U = 1.2 \text{ Dead} + 1.0 \text{ Seismic} + 0.5 \text{ Live}$
- $U = 0.9 \text{ Dead} + 1.6 \text{ Wind} + 1.6 \text{ Earth Pressure}$
- $U = 0.9 \text{ Dead} + 1.0 \text{ Seismic} + 1.6 \text{ Earth Pressure}$

3.2.7.2 Steel Structures. The required strength (S) based on elastic design methods and allowable stresses (without $\frac{1}{3}$ increase allowed for wind or seismic loading) defined in the AISC Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design, will be at least equal to the following:

- $S = \text{Dead}$
- $S = \text{Dead} + \text{Live}$
- $S = 0.75 (2/3 \text{ Dead} + \text{Wind})$
- $S = 0.75 (0.9 \text{ Dead} + \text{Seismic}/1.4)$
- $S = 0.75 (\text{Dead} + \text{Live} + 1.3 \text{ Wind})$

- $S = 0.75 (\text{Dead} + \text{Live} + \text{Seismic}/1.4)$

For load combinations including seismic loading, frame members and connections will conform to the additional requirements of Sections 1633A and 2213A of the CBC.

3.2.8 Factors of Safety

Minimum factors of safety for structures, tanks, and equipment supports will be as follows:

- Overturning - 1.50
- Sliding - 1.50
- Buoyancy - 1.25
- Uplift due to wind - 1.50

3.3 Materials

3.3.1 Structural Steel

3.3.1.1 General. Structural steel will conform to ASTM A572, GR 50 or other materials as required and accepted for use by the AISC Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design.

High-strength bolts for connections will conform to ASTM A325. Bolts other than high-strength bolts will conform to ASTM A307, Grade A. Nonheaded anchor bolts will conform to ASTM A36, unless higher strength bolting materials are required by design. Drilled-in expansion bolts for concrete will be Hilti-Kwik Bolt TZ, designed in accordance with ICC ESR-1917.

Structural steel will be detailed and fabricated in accordance with the AISC Code of Standard Practice and the AISC Specification for Structural Steel Buildings. Structural material will be fabricated and assembled in the shop to the greatest extent possible. Structural members will be welded in accordance with AWS D1.1. Columns will be milled to bear on the baseplate or cap plate. Connections will have a minimum of two bolts.

Exterior structural steel will be either hot-dip galvanized or shop primed and finish painted after installation. Interior structural steel will be shop primed after fabrication. Surface preparation and painting will be in accordance with Steel Structures Painting Council standards. Galvanizing will be in accordance with the requirements of ASTM standards.

3.3.1.2 Design and Testing. Steel structures will be designed by the Working Stress Method in accordance with the CBC and the AISC Specification for Structural Steel

Buildings, Allowable Stress Design and Plastic Design. Connections will be in accordance with the AISC Manual of Steel Construction and the AISC Allowable Stress Design Specification for Structural Joints Using ASTM A325 or A490 Bolts.

Steel structures will be designed as "rigid frame" (ABC Specification Type 1) or "simple framing" (AISC Specification Type 2), using single-span beam systems, vertical diagonal bracing at main column lines, and horizontal bracing at the roof and major floor levels.

Type I rigid frames will be generally limited to prefabricated metal buildings. All other framed structures will use Type 2 design and construction.

Metal roof and floor decking attached with appropriate welding or fasteners may be considered effective as horizontal diaphragms, provided they are previously qualified by the manufacturer. Grating floors will not be considered as providing horizontal rigidity.

Mill test reports or certificates of conformance will be required certifying that material is in conformance with the applicable ASTM specification. In addition, the fabricator will be required to provide an affidavit stating that steel has been furnished in accordance with the requirements of the drawings and the specifications, including specified minimum yield strength.

3.3.1.3 Handrails, Guardrails, and Toe Plates. Handrails and/or guardrails, except for pre-engineered equipment, will be fabricated from standard weight steel pipe and fittings, either galvanized or painted. Handrails will have toe plates where there is no cur

3.3.1.4 Steel Grating and Grating Stair Treads. The steel to be used for grating and grating treads will conform to either ASTM A36 or ASTM A569. Grating will be rectangular and consist of welded steel construction. Grating will be hot-dip galvanized after fabrication.

Stair treads will have nonslip abrasive nosing and will have end plates for attaching to stringers. Outdoor grating will have a serrated surface.

The Hilti Grating Disk system, or equivalent, will be used for fastening. Grating will have at least a 1 inch bearing support.

Floor and platform openings necessitated by expansion and movement requirements around piping and equipment will be protected as follows:

- Openings exceeding 1-1/2 inches wide around penetrating objects will be protected by toe plates.

- Openings exceeding 8 inches wide around penetrating objects will be protected by toe plates and handrails.

3.3.1.5 Stairs and Ladders. Stairs will be the means of travel from one elevation to another. Vertical ladders, ship ladders, etc., will be installed only where personnel access is infrequent.

Fixed ladders will have safety cages and/or other fall-prevention devices as required by the applicable codes and regulations. Stairs will have handrails on both sides.

3.3.2 Concrete and Reinforcing Steel

3.3.2.1 General. Materials for concrete will comply with ACI 301. Cement will be Portland cement meeting the requirements of ASTM C 150. Fine aggregates will be clean natural sand. Coarse aggregates will be crushed stone or gravel. Aggregates will conform to the chemical and physical requirements of ASTM C33. Only clean water of potable quality and satisfying the requirements of ASTM C94 will be used.

Admixtures such as plasticizers and retarders may be used to improve workability and control setting time. Concrete will have entrained air content between 3 and 6 percent by volume. Air entraining admixtures will meet ASTM C260 requirements. Water reducing admixtures will conform to ASTM C494, Type A. Calcium chloride or admixtures containing calcium chloride will not be used.

Concrete reinforcing will be deformed bars of intermediate grade billet steel conforming to ASTM A615, Grade 60, or welded wire fabric conforming to ASTM A 185.

3.3.2.2 Mix Design. Concrete mix designs will be proportioned and furnished in accordance with ACI 211.1, ASTM C94, and CBC Section 1905A. Proportions for the concrete mixture will be selected to meet the strength requirements specified in design documents. Generally, a minimum concrete compressive strength of 4,000 psi at 28 days will be required for structural concrete. Final concrete mix designs will be established based on historical strength performance data or trial mixtures meeting the requirements of Section 1905A of the CBC.

3.3.2.3 Testing and Material Certification. Certified mill test reports on chemical and physical properties confirming compliance with ASTM C150 will be required for each shipment of cement used.

Certificates of Conformance will be obtained from the Supplier certifying that aggregates used comply with the chemical and physical requirements of ASTM C33. Gradation analyses of fine and coarse aggregates, performed in accordance with ASTM 0135, will also be

provided.

Manufacturer will certify that the admixture provided conforms to the specified ASTM standard and that it contains no chlorides except those that may be contained in the water used in manufacturing the admixture.

The slump, air content, and temperature of the concrete at the point of discharge from the conveying vehicle will be tested in accordance with specified minimum testing frequencies. Concrete strength will be evaluated in accordance with ASTM C94 and CBC Section 1905A.

Mill test reports certifying that reinforcing steel is in accordance with ASTM and project specifications will be required.

3.3.2.4 Design. Reinforced concrete structures will be designed by the Ultimate Strength Method in accordance with the CBC and ACI 318, Building Code Requirements for Reinforced Concrete.

3.4 Seismic Design Criteria

This section provides the general criteria and procedures to be used for the seismic design of buildings, structures, and structural components.

3.4.1 Seismic Performance Objectives

The seismic performance objectives for this facility are:

- Resist minor levels of earthquake ground motion without damage.
- Resist moderate levels of earthquake ground motion without structural damage, but with some nonstructural damage.
- Resist major levels of earthquake ground motion without collapse, but with some structural as well as nonstructural damage.

To achieve these objectives and to meet the requirements of the California Energy Commission (CEC) and local codes, the facility will be designed in accordance with the CBC.

3.4.2 General Criteria

The plant site is located in Seismic Category D according to CBC Chapter 16. For seismic load calculations, the Importance Factor for Category 3 structures (power plants) is 1.25 based

on ASCE 7-05 Table 11.5-1. Accordingly, an Importance Factor of 1.25 will be used for all plant buildings, structures, and structural components except special use structures requiring higher Importance Factors as noted in Table B-1.

Buildings and structures will be designed in accordance with ASCE 7-05 Chapter 12. Nonbuilding structures will be designed in accordance with ASCE 7-05 Chapter 15, and nonstructural components will be designed in accordance with ASCE 7-05 Chapter 13.

In addition to 2007 CBC requirements, water storage tanks will meet the seismic design requirements of AWWA D100, Appendix C.1.

3.4.3 Critical Structures

Critical structures are those structural components that are necessary for power production and are costly to repair or replace or that require a long lead time to repair or replace; or are used for the storage, containment, or handling of hazardous or toxic materials.

Seismic loads for critical structures will be determined by the equivalent lateral force procedure of ASCE 7-05. Table B-1 identifies the critical structures and the associated seismic load coefficients that will be used in their design.

3.5 Architecture

3.5.1 General

Architectural work will be in accordance with the applicable laws, ordinances, codes and industry standards, design criteria, guidelines, general requirements, and material selection specified in this section.

The plant will be laid out to accommodate the spaces required for plant equipment and operations. Aisles and clearances will provide access for operation, minor maintenance, and equipment removal. Personnel walkways to equipment (for routine maintenance only), doors, stairs, and other access points will be provided. Plant security and life safety features will also be considered in the plant layout.

3.5.2 Criteria

These criteria are intended to govern the architectural design of structures and facilities.

Safety, construction, fire protection and fire walls, and requirements for the physically handicapped will be in accordance with the requirements of the applicable local, state, and national codes and standards. Requirements of the Americans with Disabilities Act will also

he included in the design.

Generally, plant buildings will be single-story, pre-engineered metal, with insulated siding. For sloping roofs, roofing will be standing seam metal with insulation and a vapor barrier; for flat roofs, roofing will be single-ply membrane over metal decking with insulation.

The administration/control building will include control room, men's and women's toilet, locker room and shower facilities, library, conference room, lunchroom, offices, and utility rooms.

The control room, offices, library, lunchroom, corridors, conference room, and toilet/locker areas will have suspended acoustical ceilings. Electrical rooms and HVAC equipment spaces will have exposed structure.

Reinforced concrete grade slabs will be treated with a sealer and/or floor hardener, as applicable, to accommodate maintenance or laydown. Interior wall partitions will be concrete block masonry, concrete, or gypsum wallboard on metal studs. Stairs will be concrete, galvanized grating, or checkered plate. Floor drains will be provided as necessary.

3.5.3 Materials

Asbestos- and lead-containing materials will not be used in the facility.

3.5.3.1 Concrete Masonry. Concrete masonry unit (CMU) partitions will generally be used in traffic and spillage areas, in toilets and locker rooms, in the battery and electrical rooms, and as fire boundaries where required by code.

CMU will be both hollow, normal weight, nonload-bearing Type 1 conforming to ASTM C 129, and load-bearing Grade N. Type I conforming to ASTM C 90. Mortar will conform to ASTM C 270; Type M. CMU will be reinforced as required.

Masonry structures will be designed and constructed in accordance with ACI 530, Building Code Requirements for Masonry Structures; ACI 530.1, Specifications for Masonry Structures; and Chapter 21 of the CBC.

3.5.3.2 Preformed Metal Siding. Exterior siding will be either an insulated or an uninsulated field-assembled system. Exterior face panels will be 24 gauge minimum; interior face panels will be 22 gauge minimum. Panels will be fabricated from galvanized sheet steel.

The wall system will be designed to withstand the specified wind loading with practical and economical support girt spacing.

Wall insulation will be noncombustible glass fiber to produce a maximum U-factor of 0.08 Btu/hr/ft²·°F.

3.5.3.3 Metal Studwall Partitions. Except when CMU partitions are required, ceiling-height interior partitions will generally be of metal stud and painted gypsum board construction.

3.5.3.4 Roofing. Roofing will be either single-ply membrane over rigid insulation board, mechanically fastened to the metal roof deck, or standing seam metal with insulation and vapor barrier. The completed roofing system will conform to UL requirements for Class A roofs and to Factory Mutual wind uplift Class 90. The completed roof will have an overall maximum U-factor of 0.05 Btu/hr/ft²/°F.

3.5.3.5 Metal Roll-Up Doors. Roll-up doors will have insulated door curtains constructed of interlocking roll-formed galvanized steel slats to withstand the specified wind pressure. Doors will be manually operated.

3.5.3.6 Hollow Metal Doors, Frames, and Hardware. Personnel doors will be flush hollow metal on pressed steel doorframes, with hinges, locksets, closers, weatherstripping, and accessory hardware. Fire doors and frames will conform to NFPA 80 for the class of door furnished.

3.5.3.7 Louvers. Louvers will be operable, extruded-aluminum section alloy, with stainless steel fastenings and removable aluminum bird screen. Blades will be stormproof. Louver free area will be a minimum of 50 percent of louver face area. Louvers will be designed for manual or gravity operation.

3.5.3.8 Floor Finish. Floor finishes will generally be concrete with curing and sealing protection. The battery room and other chemical areas will generally receive special coatings.

3.5.4 Painting

Generally, exposed wall surfaces, structures, and structural components will be prime painted or otherwise treated to protect them from corrosion in accordance with the applicable codes, industry standards, and manufacturer's recommendations.

3.5.4.1 Structural and Miscellaneous Steel. Structural and miscellaneous steel will receive shop-applied inorganic zinc primer. Field touchup will be performed after erection. Structural steel requiring fireproofing will either receive no painting or a primer compatible with the selected fireproofing material.

3.5.4.2 Masonry Walls and Concrete Walls and Floors. Concrete floors in areas not exposed to chemical contaminants will not be coated. Indoor masonry walls in areas requiring paint but not exposed to chemical contaminants will be painted with one coat of acrylic filler and a compatible finish coat.

3.5.4.3 Gypsum Wallboard. Exposed surfaces will receive one coat each of sealer and compatible acrylic finish.

4 STRUCTURAL DESIGN METHODOLOGY

This section describes the structural aspects of the design of the proposed facility. Each major structural component of the plant is addressed by defining the design criteria and analytical techniques that will be employed.

4.1 Structures

4.1.1 Steam Turbine Foundation

The steam turbine foundation will be designed to support the turbine and generator components.

The foundation will be designed to resist the loadings furnished by the manufacturer plus loadings from natural phenomena and structural framing, if applicable, and will be constructed of reinforced concrete.

4.1.1.1 Foundation Loads. Equipment foundation loads will be furnished by the combustion and steam turbine manufacturer and will be combined with the other loads imposed on the foundation. Typical loading data supplied by the manufacturer include the following. The combustion and steam turbine foundations will be designed for these loads:

- Dead loads
- Live loads
- Wind loads
- Seismic loads
- Normal torque loads
- Normal machine unbalance loads

- Emergency loads, such as turbine accident or generator short-circuit
- Thermal loads due to thermal expansion or contraction of the machines, connected piping, and turbine pedestal components
- Shrinkage and creep loads
- Condenser vacuum load (steam turbine only)

4.1.1.2 Induced Forces. The steam turbines and associated equipment will be securely anchored to their foundations using cast-in-place steel anchor bolts designed to resist the equipment forces and seismic or wind loads.

4.1.1.3 Structural System. The combustion turbine foundation system will consist of a reinforced concrete mat bearing directly on a Deep Soil Mixed foundation system. The steam turbine generator will be provided with a reinforced concrete rigid frame pedestal and a reinforced concrete mat bearing on a Deep Soil Mixed foundation system.

4.1.1.4 Structural Criteria. Each foundation will be designed and constructed as a monolithic reinforced concrete structure using the criteria from Section 3 and Appendix C.1, Section 3.1. The foundation design will address the following considerations:

- Allowable settlements
- Equipment, structure, and environmental loads
- Factors of safety against overturning and sliding
- Equipment performance criteria
- Natural frequencies and dynamic effects of rotating equipment
- Access and maintenance

Soil pressures will satisfy the allowable bearing pressure criteria that will be developed during project detailed design to provide a safety factor against bearing failure. Total and differential settlements will be limited to the values specified in Appendix C.1, Section 3.1 .2.

Environmental loadings will be determined in accordance with Sections 3.1 and 3.2. Foundation seismic loading will be calculated as specified in Section 3.4. Seismic forces will be applied at the center of gravity of the equipment.

Load combinations and their respective strength requirements for the foundation design will be as indicated in Sections 3.2.6 and 3.2.7. Factors of safety against overturning and sliding will satisfy the requirements of Section 3.2.8.

4.1.1.5 Analytical Techniques.

Steam Turbine Pedestal and Foundation. Computer analyses will be used for both static and dynamic loads on the steam turbine pedestal and foundation. The pedestal deck and columns will be modeled as a 3-dimensional (3-D) space frame structure using 3-D beam elements. The foundation mat will be modeled using 3-D plate bending elements.

The interaction between the mat and the Deep Soil Mixed foundation system will be modeled using a system of vertical and horizontal springs attached to a fixed boundary.

Static analyses will be performed to obtain structure displacements and internal forces and moments produced by the static portion of the load combinations, including seismic loads. Dynamic analyses will be performed to confirm the adequacy of the pedestal and foundation to support the operating machinery and sustain the dynamic loads associated with machinery operation within specified displacement and stress limits. Dynamic analyses may not be required where the effects of particular dynamic loads are specified by the manufacturer in terms of equivalent static loads.

4.1.2 Buildings and Enclosures

The various plant buildings and enclosures will provide support, protection, and access to the systems contained within their boundaries. Generally, each building and enclosure will be one story and pre-engineered.

4.1.2.1 Foundation Loads. Foundation loads will be determined from the analysis and design of the superstructure and from the support of the equipment contained within the structure. The following loads will be considered:

- Dead loads
- Live loads
- Equipment and piping loads
- Wind loads
- Seismic loads

4.1.2.2 Induced Forces. Each building and enclosure will be securely anchored to its foundation using cast-in-place steel anchor bolts designed to resist any induced forces.

4.1.2.3 Structural System. Buildings and enclosures will be designed as AISC Type 1 rigid frames or as Type 2 simple braced frames. For the purpose of resisting seismic lateral loads, the structures will be classified as ordinary structures with a concentric braced frame, an ordinary moment-resisting frame, or a special moment-resisting frame, in accordance with the definitions of ASCE 7-05.

The foundation systems for buildings and enclosures will typically consist of individual spread footings to resist the column loads, and an isolated slab-on-grade floor system.

4.1.2.4 Structural Criteria. Building and enclosure steel frames will be designed and constructed using the materials and criteria set forth in Section 3.

Environmental loading will be determined in accordance with Sections 3.1 and 3.2.

Building and enclosure foundations will be designed and constructed using reinforced concrete according to the criteria set forth in Section 3 and Appendix C.1, Section 3.1. The foundation design will address the following considerations:

- Allowable soil pressures or Deep Mixed Soil foundation system capacities
- Allowable settlements
- Equipment, structure, and environmental loads
- Factors of safety against overturning and sliding
- Equipment performance criteria
- Access and maintenance

Soil pressures will satisfy the allowable bearing pressure criteria that will be developed during project detailed design to provide a minimum safety factor of three against bearing failure. Total and differential settlements will be limited to the values specified in Appendix C.1, Section 3.1.2.

Load combinations and their respective strength requirements for the foundation design will be as indicated in Sections 3.2.6 and 3.2.7. Factors of safety against overturning and sliding will satisfy the requirements of Section 3.2.8.

4.1.2.5 Analytical Techniques. Building and enclosure foundations will be designed as simple spread footings or mat foundations, using static analysis techniques. The foundations will be analyzed assuming a linear soil pressure distribution.

4.2 Tanks

4.2.1 Field-Erected Storage Tanks

Field-erected storage tanks will typically be vertical, cylindrical shells consisting of stainless steel or carbon steel construction with a protective interior coating. Tank roofs will be either self-supported domes or cones. Tank bottoms will be ground-supported, flat-bottomed, with a slope of 1 percent. Tanks will have ladders, landing platforms, and handrails to provide access to working areas. Vents, manholes, overflow piping, and grounding lugs will be provided as necessary.

4.2.1.1 Foundation Loads. Foundation loads will be determined using project-specific design criteria. Tank and foundation design will include the following loads:

- Dead loads (including contained fluid load)
- Live loads
- Wind loads
- Seismic loads (including hydrodynamic loads)

4.2.1.2 Induced Forces. Storage tanks will be securely anchored to their foundations using cast-in-place steel anchor bolts designed to resist tank-induced forces.

4.2.1.3 Structural System. Each tank will be a cylindrical steel shell that resists lateral loading through shear in the tank wall. Overturning will be resisted by anchor bolts connecting the tank wall to the foundation.

The tank foundation system will typically consist of a reinforced concrete ringwall or mat foundation. The interior of the ring will consist of compacted backfill with a layer of compacted sand to serve as a bearing surface for the tank bottom. If soil conditions could result in excessive settlements or soil overstress, a complete concrete mat may be required.

4.2.1.4 Structural Criteria. Tank structures will be designed and constructed using the criteria established in AWWA D100 or NFPA 22, as applicable.

Foundations will be designed and constructed as reinforced concrete structures using the criteria from 3 and Appendix C.1, Section 3.1. Foundation design will address the following considerations:

- Allowable soil pressures or allowable pile capacities
- Allowable settlements
- Fluid, structure, and environmental loads
- Factors of safety against overturning and sliding

Total and differential settlements will be limited to the values specified in Appendix C.1, Section 3.1.2.

Environmental loadings will be determined in accordance with Sections 3.1 and 3.2. Seismic loads will be determined in accordance with Section 3.4 and AWWA D100, Section 13.

Load combinations and their respective strength requirements for the foundation design will be as indicated in Sections 3.2.6 and 3.2.7 and in Section 3 of AWWA D100. Factors of safety against overturning and sliding will satisfy the requirements of Section 3.2.8.

Tank foundation design will include the moment resulting from lateral displacement (hydrodynamics) of the tank contents in accordance with AWWA D100, Section 13.3.3.2.

4.2.1.5 Analytical Techniques. Tank foundations will typically be designed as circular ringwalls using static analysis techniques. Each ringwall will be proportioned to resist the design load of the tank and the maximum overturning moment due to wind or seismic loading. The ringwall will also be proportioned to resist maximum anchor bolt uplift force. Circumferential reinforcing steel will be provided in the ringwall to develop the hoop stress produced by the lateral soil pressure within the ringwall.

Tank structures will be designed and proportioned such that during the application of any load, or combination of loads, the allowable stresses as stipulated in AWWA D100 are not exceeded.

4.2.2 Shop-Fabricated Storage Tanks

Shop-fabricated storage tanks will be either vertical or horizontal, cylindrical, carbon steel shells. The tanks will have ladders, landing platforms, and handrails, to provide access to working areas. Each tank will have nozzles for fill connection, fill drain, overflow, vent connections, manholes, and grounding lugs as necessary.

4.2.2.1 Foundation Loads. Foundation loads will be furnished by the tank manufacturer and will be superimposed with loads for the foundation itself.

Typical loadings supplied by the manufacturer include:

- Dead loads
- Live loads
- Wind loads
- Seismic loads (including hydrodynamic loads)
- Temperature and pressure loads

4.2.2.2 Induced Forces. Each tank will be securely anchored to its foundation using cast-in-place steel anchor bolts or concrete expansion anchors designed to resist tank-induced forces.

4.2.2.3 Structural System. Each tank will consist of a cylindrical steel shell, either supported by integral legs or saddle supports, or with a flat bottom bearing directly on the foundation.

Foundations will typically consist of individual pads bearing directly on Deep Mixed Soil foundation system capacities or compacted fill. For tanks located in buildings, the pads may be constructed integrally with the grade slab

4.2.2.4 Structural Criteria. Tanks will be designed by a tank manufacturer in accordance with the relevant ASME code, ANSI code, and ASTM standards.

Foundations will be designed and constructed as monolithic reinforced concrete structures using the criteria from Section 3 and Appendix C.1, Section 3.1. Foundation design will address the following considerations:

- Allowable soil pressures or Deep Mixed Soil foundation systems
- Allowable settlements
- Fluid, structure, and environmental loads
- Factors of safety against overturning and sliding

Soil pressures or loads will satisfy the allowable bearing pressure criteria or Deep Mixed Soil foundation system capacities that will be developed during project detailed design. Total and differential settlements will be limited to the values specified in Appendix C.1, Section 3.1.2.

Environmental loadings will be determined in accordance with Sections 3.1 and 3.2. Seismic loading will be calculated using equivalent static lateral forces applied at the center of gravity of the tank or tank component in accordance with the criteria specified in Section 3.4.

Load combinations and their respective strength requirements for the foundation design will be as indicated in Sections 3.2.6 and 3.2.7. Factors of safety against overturning and sliding will satisfy the requirements of Section 3.2.8.

4.2.2.5 Analytical Techniques. The tank foundations will typically be designed using static analysis techniques assuming a rigid mat. The foundations will be analyzed assuming a linear soil pressure distribution. The mats will be proportioned such that the resultant of the soil pressure coincides as nearly as possible with the resultant of the vertical loading.

The tanks will be designed and analyzed by a tank manufacturer to satisfy the requirements of the relevant ASME code, ANSI code, and ASTM standards.

4.3 Equipment and Equipment Foundations

Plant equipment will be designed in accordance with manufacturers' standards and applicable codes and industry standards. Equipment will be designed to resist project-specific environmental loadings, as applicable.

Foundations will be designed to resist the loadings furnished by the manufacturers and will be constructed of reinforced concrete.

Specific criteria for the steam turbine foundation is addressed in Sections 4.1.1.

4.3.1 Equipment/Foundation Loads

Equipment and foundation loads will be determined by the manufacturers using project-specific design criteria. Typical loadings used for design will include:

- Dead loads
- Live loads
- Operating loads
- Wind loads
- Seismic loads
- Emergency loads

Foundation loads furnished by the equipment manufacturers will be superimposed with loads for the foundation itself.

4.3.2 Induced Forces

The equipment will use steel anchor bolts, concrete expansion anchors, welds, and other equipment anchorage devices to resist equipment-induced forces.

4.3.3 Structural System

Foundations will typically consist of individual pads bearing directly on a Deep Mixed Soil foundation system or compacted fill. For equipment located in buildings, the pads may be constructed integrally with the grade slab

4.3.4 Structural Criteria

Plant equipment will be designed to resist project-specific criteria in accordance with the manufacturers' standards and applicable codes and industry standards.

Environmental loading will be determined in accordance with Sections 3.1 and 3.2. Seismic loading will be calculated using equivalent static lateral forces applied at the center of gravity of the equipment or component in accordance with the criteria specified in Section 3.4.

Seismic lateral forces on equipment supported by structures will be determined in accordance

with ASCE 7-05 Chapter 13, with I_p equal to 1.5 for fire equipment and 1.25 for other equipment. Equipment bases, foundations, support frames, and structural members used to transfer equipment seismic forces to the main lateral load-resisting system will be designed for the same seismic load as the equipment.

Load combinations will be as indicated in Section 3.2.6. These load combinations are in addition to those normally used in design and those specified in applicable codes and standards.

Equipment foundations will be designed and constructed as monolithic reinforced concrete structures using the criteria from Section 3 and Appendix C.1, Section 3.1. The foundation design will address the following considerations:

- Allowable soil pressures or a Deep Mixed Soil foundation system
- Allowable settlements
- Equipment and environmental loads
- Factors of safety against overturning and sliding
- Equipment performance criteria
- Access and maintenance

Soil pressures will satisfy the allowable bearing pressure criteria, or Deep Mixed Soil foundation system that will be developed during project detailed design. Total and differential settlements will be limited to the values specified in Appendix C.1, Section 3.1.2.

Load combinations and their respective strength requirements for the foundation design will be as indicated in Sections 3.2.6 and 3.2.7. Factors of safety against overturning and sliding will satisfy the requirements of Section 3.2.8.

4.3.5 Analytical Techniques

Equipment foundations will typically be designed using static analysis techniques assuming a rigid mat. Foundations will be analyzed assuming a linear soil pressure distribution. Mats will be proportioned such that the resultant of the soil pressure coincides as nearly as possible with the resultant of the vertical loading.

Equipment will be designed and analyzed by the manufacturer to satisfy the requirements of the relevant codes and industry standards.

5 HAZARD MITIGATION

The project will be designed to mitigate natural and environmental hazards caused by seismic and meteorological events. This section addresses the structural design criteria used to

mitigate such hazards.

5.1 Seismic Hazard Mitigation Criteria

Appendix C.1 and this appendix describe the civil and structural design criteria that will be applied to the project.

Project seismic design criteria were selected based on the following considerations:

- Compliance with applicable laws, ordinances, regulations, codes, and standards
- Life safety
- Structural behavior and performance
- Reliability of the plant
- Financial impacts from seismically induced outages
- Seismic probability and magnitude

The project seismic design criteria were developed to incorporate these considerations using a systematic approach to correlate performance criteria with assumed risk level. The following procedure was used to establish the design criteria:

- The seismic hazards were assessed by studying the geologic features of the surrounding area. Major faults were identified, and information was collected regarding each fault's proximity, capability, recurrence, and magnitude.
- The seismic risk associated with each source was assessed considering historical magnitudes.
- Appropriate design criteria and analysis methods consistent with the seismic performance criteria were established for each major plant structure, equipment, and component.

Specific design features that will be incorporated into the plant to mitigate the identified seismic hazards include:

- Appropriate analysis techniques will be employed to calculate structure-specific seismic loads.
- Plant structures, equipment, piping, and other components will be designed to resist the project-specific seismic loads.
- Critical equipment will be positively anchored to its supporting structure.

- Anchorages will be designed to resist project-specific seismic loadings.
- Adequate factors of safety against overturning and sliding due to seismic loads will be provided.
- The design of piping connections to structures, tanks, and equipment will consider differential seismic displacements between components.
- Adjacent structures will be seismically isolated from one another.
- Structural elements will be designed to comply with special detailing requirements intended to provide ductility.
- Connections for steel structures will have a minimum load carrying capability without regard to the calculated load.
- Lateral and vertical displacements of structures and elements of structures will be limited to specified values.
- Appropriate measures will be taken for soil liquefaction to limit damage.

The foregoing design features are intended to provide the degrees of safety for structures and equipment as follows:

- Resist minor earthquakes without damage. Plant remains operational.
- Resist moderate earthquakes without structural damage but with some nonstructural damage. Plant remains operational or is returned to service following visual inspection and/or minor repairs.
- Resist major earthquakes without collapse but with some structural and nonstructural damage. Plant is returned to service following visual inspection and/or moderate repairs.

5.2 Meteorological And Climatic Hazard Mitigation

Meteorological and climatic data were used to establish the project design basis. Portions of the data and the design bases that pertain to structural engineering are provided in this appendix.

Specific design features that will be incorporated into the plant to mitigate meteorological and climatic hazards include:

- Structures and cladding will be designed to resist the wind forces.

- Sensitive structures will be designed for wind-induced vibrational excitation.
- Roofs will be sloped and equipped with drains to prevent accumulation of rainfall.
- Site drainage systems will be designed to convey the runoff from a 24 hour rainfall event with a 10 year recurrence interval.
- Ground floor levels of structures will be placed minimum 6" above finished grade.
- A variable height dike will completely surround the project site.
- Building drain lines will be installed with backflow prevention devices.
- The bases of plant equipment will be placed minimum 6" above finished grade.
- The plant site will be graded to convey runoff away from structures and equipment.

The foregoing design features will be incorporated in accordance with the applicable codes and standards identified in this appendix.

The degree of safety offered by these features is consistent with the requirements of the applicable codes and standards and the economic benefits these features provide.

TABLE B-1
SEISMIC LOAD COEFFICIENTS OF CRITICAL STRUCTURES

Critical Structure	Importance Factor (I)
Fire Pump Building	1.5
Other Buildings	1.25
Fire Water Tank	1.5
Flat Bottom Tanks and Their Foundations and Anchorage	1.25
Other Tanks and Their Foundations and Anchorage	1.25
Foundations for Steam Turbine/Generator	1.25

APPENDIX C.3

Mechanical Engineering Design Criteria

1 Introduction

This appendix summarizes the codes, standards, criteria, and practices that will be generally used in the design and construction of mechanical engineering systems for the Salton Sea Unit 6 Geothermal Generation Station. More specific project information will be developed during execution of the project to support detailed design, engineering, material procurement specification, and construction specifications.

2 Codes and Standards

The design of the mechanical systems and components will be in accordance with the laws and regulations of the federal government, state of California, County of San Bernardino ordinances, and industry standards. The current issue or revision of the documents at the time of the filing of this Application for Certification (AFC) will apply, unless otherwise noted. If there are conflicts between the cited documents, the more conservative requirements shall apply.

The following codes and standards are applicable to the mechanical aspects of the power facility.

- California Building Standards Code, 2007
- American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code
- ASME B31.1 Power Piping Code
- ASME B31.3 Process Piping Code
- ASME Performance Test Codes
- ASME Standard TDP-1
- American National Standards Institute (ANSI) B16.5, B16.34, and B133.8
- American Boiler Manufacturers Association (ABMA)
- American Gear Manufacturers Association (AGMA)
- Air Moving and Conditioning Association (AMCA)
- American Society for Testing and Materials (ASTM)
- American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE)
- American Welding Society (AWS)
- Cooling Tower Institute (CTI)
- Heat Exchange Institute (HEI)
- Manufacturing Standardization Society (MSS) of the Valve and Fitting Industry
- National Fire Protection Association (NFPA)
- Hydraulic Institute Standards (HIS)
- Tubular Exchanger Manufacturer's Association (TEMA)

3 Mechanical Engineering General Design Criteria

3.1 General

The systems, equipment, materials, and their installation will be designed in accordance with the applicable codes; industry standards; and local, state, and federal regulations, as well as the design criteria; manufacturing processes and procedures; and material selection, testing, welding, and finishing procedures specified in this section.

Detailed equipment design will be performed by the equipment vendors in accordance with the performance and general design requirements to be specified later by the project A/E firm. Equipment vendors will be responsible for using construction materials suited for the intended use.

3.2 Materials—General

Asbestos will not be used in the materials and equipment supplied. Where feasible, materials will be selected to withstand the design operating conditions, including expected ambient conditions, for the design life of the plant. It is anticipated that some materials will require replacement during the life of the plant due to corrosion, erosion, etc.

3.2.1 Pumps

Pumps will be sized in accordance with industry standards. Where feasible, pumps will be selected for maximum efficiency at the normal operating point. Pumps will be designed to be free from excessive vibration throughout the operating range.

3.2.2 Tanks

Large outdoor storage tanks will not be insulated except where required to maintain appropriate process temperatures or for personnel protection.

Overflow connections and lines will be provided. Maintenance drain connections will be provided for complete tank drainage.

Manholes, where provided, will be at least 24 inches in diameter and hinged to facilitate removal. Storage tanks will have ladders and cleanout doors as required to facilitate access/maintenance. Provisions will be included for proper tank ventilation during internal maintenance.

3.2.3 Heat Exchangers

The surface condenser will be designed in accordance with Heat Exchange Institute (HEI) standards. Other heat exchangers will be provided as components of mechanical equipment packages and may be shell-and-tube. Heat exchangers will be designed in accordance with TEMA or manufacturer's standards. Fouling factors will be specified in accordance with TEMA.

3.2.4 Pressure Vessels

Pressure vessels will include the following features/appurtenances:

- Process, vent, and drain connections for startup, operation, and maintenance
- Materials compatible with the fluid being handled
- A minimum of one manhole and one air ventilation opening (e.g., handhole) where required for maintenance or cleaning access
- For vessels requiring insulation, shop-installed insulation clips spaced not greater than 18 inches on center
- Relief valves in accordance with the applicable codes

3.2.5 Piping and Piping Supports

Brine handling and steam production piping shall be designed, fabricated, installed, and tested in accordance with ASME B31.1 Process Piping. All other piping shall be designed, fabricated installed, and tested in accordance with ASME B31.1 Power piping.

Stainless steel pipe may be Schedule 5S or 10S where design pressure permits. Underground piping may be high-density polyethylene (HDPE) or polyvinyl chloride (PVC) where permitted by code, operating conditions, and fluid properties. In general, water system piping will be HDPE or PVC where embedded or underground and carbon steel where aboveground. Appropriately lined and coated carbon steel pipe may alternately be used for buried water piping.

Threaded joints will not normally be used in piping used for lubricating oil, and natural gas service. Natural gas piping components will not use synthetic lubricants. Victaulic, or equal, couplings may be used for low-energy aboveground piping, where feasible.

Piping systems will have high-point vents and low-point drains. Drains with restricting orifices or steam traps with startup and blowdown drains and strainers will be installed in low points of steam lines where condensate can collect during normal operation.

Steam piping systems and steam drain lines in the plant will typically be sloped in the direction of steam flow. Condensate collection in piping systems will be avoided by installing automatic drain devices and manual devices as appropriate.

Steam lines fitted with restricting devices, such as orifices in the process runs, will include adequate drainage upstream of the device to prevent condensate from collecting in lines.

Hose and process tubing connections to portable components and systems will be compatible with the respective equipment suppliers' standard connections for each service.

Stainless steel piping will be used for portions of the lubricating oil system downstream of the filters. Carbon steel piping may be used elsewhere.

3.2.6 Valves

3.2.6.1 General Requirements

Valves will be arranged for convenient operation from floor level where possible and, if required, will have extension spindles, chain operators, or gearing. Hand-actuated valves will be operable by one person. Gear operators will be provided on manual valves 8 inches or larger.

Valves will be arranged to close when the handwheel is rotated in a clockwise direction when looking at the handwheel from the operating position. The direction of rotation to close the valve will be clearly marked on the face of each handwheel.

The stops that limit the travel of each valve in the open or closed position will be arranged on the exterior of the valve body. Valves will be fitted with an indicator to show whether they are open or closed; however, only critical valves will be remotely monitored for position.

Valve materials will be suitable for operation at the maximum working pressure and temperature of the piping to which they are connected. Steel valves will have cast or forged steel spindles. Seats and faces will be of low-friction, wear-resistant materials. Valves in throttling service will be selected with design characteristics and of materials that will resist erosion of the valve seats when the valves are operated partly closed.

Valves operating at less than atmospheric pressure will include means to prevent air in-leakage. No provision will be made to repack valve glands under pressure.

3.2.6.2 Drain and Vent Valves and Traps

Drains and vents in 600-pound class or higher piping and 900°F or higher service will be double-valved.

Drain traps will include air cock and easing mechanism. Internal parts will be constructed from corrosion-resistant materials and will be renewable.

Trap bodies and covers will be cast or forged steel and will be suitable for operating at the maximum working pressure and temperature of the piping to which they are connected. Traps will be piped to drain collection tank or sumps and returned to the cycle if convenient.

3.2.6.3 Low Pressure Water Valves

Low-pressure water valves will be the butterfly type of cast iron construction. Ductile iron valves will have ductile iron bodies, covers, gates (discs), and bridges; the spindles, seats, and faces will be bronze. Fire protection valves will be Underwriters Laboratories (UL)-approved butterfly valves meeting NFPA requirements.

3.2.6.4 Instrument Air Valves

Instrument air valves will be the ball type of bronze construction, with valve face and seat of approved wear-resistant alloy.

3.2.6.5 Nonreturn Valves

Nonreturn valves for steam service will be in accordance with ANSI standards and properly drained. Nonreturn valves in vertical positions will have bypass and drain valves. Bodies

will have removable access covers to enable the internal parts to be examined or renewed without removing the valve from the pipeline.

3.2.6.6 Motor-Actuated Valves

Electric motor actuators will be designed specifically for the operating speeds, differential and static pressures, process line flowrates, operating environment, and frequency of operations for the application. Electric actuators will have self-locking features. A handwheel and declutching mechanism will be provided to allow handwheel engagement at any time except when the motor is energized. Actuators will automatically revert back to motor operation, disengaging the handwheel, upon energizing the motor. The motor actuator will be placed in a position relative to the valve that prevents leakage of liquid, steam, or corrosive gas from valve joints onto the motor or control equipment.

3.2.6.7 Safety and Relief Valves

Safety valves and/or relief valves will be provided as required by code for pressure vessels, heaters, and boilers. Safety and relief valves will be installed vertically. Piping systems that can be over-pressurized by a higher-pressure source will also be protected by pressure-relief valves. Equipment or parts of equipment that can be over-pressurized by thermal expansion of the contained liquid will have thermal relief valves.

3.2.6.8 Instrument Root Valves

Instrument root valves will be specified for operation at the working pressure and temperature of the piping to which they are connected. Test points and sample lines in systems that are 500-pound class or higher service will be double-valved.

3.2.7 Heating, Ventilating, and Air Conditioning (HVAC)

HVAC system design will be based on site ambient conditions specified in Section 2.0, Project Description.

Except for the HVAC systems serving the control room, maintenance shop, lab areas, and administration areas, the systems will not be designed to provide comfort levels for extended human occupancy.

Air conditioning will include both heating and cooling of the inlet-filtered air. Air velocities in ducts and from louvers and grills will be low enough not to cause unacceptable noise levels in areas where personnel are normally located.

Fans and motors will be mounted on anti-vibration bases to isolate the units from the building structure. Exposed fan outlets and inlets will be fitted with guards. Wire guards will be specified for belt-driven fans and arranged to enclose the pulleys and belts.

Air filters will be housed in a manner that facilitates removal. The filter frames will be specified to pass the air being handled through the filter without leakage.

Ductwork, filter frames, and fan casings will be constructed of mild steel sheets stiffened with mild steel flanges and galvanized. Ductwork will be the sectional bolted type and will be adequately supported. Duct joints will be leaktight.

Grills and louvers will be of adjustable metal construction.

3.2.8 Thermal Insulation and Cladding

Parts of the facility requiring insulation to reduce heat loss or afford personnel safety will be thermally insulated. Minimum insulation thickness for hot surfaces near personnel will be designed to limit the outside lagging surface temperature to a maximum of 140°F.

The thermal insulation will have as its main constituent calcium silicate, foam glass, fiber glass, or mineral wool, and will consist of pre-formed slabs or blankets, where feasible. Asbestos-containing materials are prohibited. An aluminum jacket or suitable coating will be provided on the outside surface of the insulation. Insulation system materials, including jacketing, will have a flame spread rating of 25 or less when tested in accordance with ASTM E 84.

Insulation at valves, pipe joints, steam traps, or other points to which access may be required for maintenance will be specified to be removable with a minimum of disturbance to the pipe insulation. At each flanged joint, the molded material will terminate on the pipe at a distance from the flange equal to the overall length of the flange bolts to permit their removal without damaging the molded insulation. Outdoor aboveground insulated piping will be clad with textured aluminum of not less than 30 mil. thickness and frame-reinforced. At the joints, the sheets will be sufficiently overlapped and caulked to prevent moisture from penetrating the insulation. Steam trap stations will be “boxed” for ease of trap maintenance.

Design temperature limits for thermal insulation will be based on system operating temperature during normal operation.

Outdoor and underground insulation will be moisture-resistant.

3.2.9 Testing

Hydrostatic testing, including pressure testing at 1.5 times the design pressure, or as required by the applicable code, will be specified and performed for pressure boundary components where an in-service test is not feasible or permitted by code.

3.2.10 Welding

Welders and welding procedures will be certified in accordance with the requirements of the applicable codes and standards before performing any welding. Records of welder qualifications and weld procedures will be maintained.

3.2.11 Painting

Except as otherwise specified, equipment will receive the respective manufacturer's standard shop finish. Finish colors will be selected from among the paint manufacturer's standard colors.

Finish painting of uninsulated piping will be limited to that required by OSHA for safety or for protection from the elements.

Piping to be insulated will not be finish painted.

3.2.12 Lubrication

The types of lubrication specified for facility equipment will be suited to the operating conditions and will comply with the recommendations of the equipment manufacturers.

The initial startup charge of flushing oil will be the equipment manufacturer's standard lubricant for the intended service. Subsequently, such flushing oil will be sampled and analyzed to determine whether it can also be used for normal operation or must be replaced in accordance with the equipment supplier's recommendations.

Rotating equipment will be lubricated as designed by the individual equipment manufacturers. Oil cups will be specified. Where automatic lubricators are fitted to equipment, provision for emergency hand lubrication will also be specified. Where applicable, equipment will be designed to be manually lubricated while in operation without the removal of protective guards. Lubrication filling and drain points will be readily accessible.

Instrumentation and Control Design Criteria

APPENDIX C.4 Instrumentation and Control Design Criteria

1 introduction

This appendix summarizes the codes, standards, criteria, and practices that will be generally used in the design and installation of instrumentation and controls for the Salton Sea 6 Units. More specific project information will be developed during execution of the project to support detailed design, engineering, material procurement specification and construction specifications.

2 Codes and Standards

The design specification of all work will be in accordance with the laws and regulations of the federal government, the state of California, and local codes and ordinances. A summary of general codes and industry standards applicable to design and control aspects of the power facility follows.

- American National Standards Institute (ANSI)
- American Society of Mechanical Engineers (ASME)
- Institute of Electrical and Electronics Engineers (IEEE)
- California Independent System Operator (CAISO)
- International Society of Automation (ISA)
- National Electrical Manufacturers Association (NEMA)
- National Electrical Safety Code (NESC)
- National Fire Protection Association (NFPA)
- North American Electric Reliability Council (NERC):
- American Society for Testing and Materials (ASTM)

3 Control Systems Design Criteria

3.1 General Requirements

The Plant Control System (PCS) will be fully integrated, flexible, and expandable microprocessor-based control and data information management system. The PCS will monitor, control, display, alarm, record and trend all assigned plant inputs and outputs as described in this section.

The system will have a distributed architecture for each operating unit based on industry standard technology including HART® and field bus technology. Each of the system functional processors will be a configurable unit programmed to execute a specific dedicated task using available advanced applications software.

The system will include:

- Windows-compatible work stations for operator interface in the central control room, including keyboard pointing devices, printers, and color graphic monitors. Additional unit control operator controls will be placed in power distribution center and at local equipment unit control panels.
- Independent process controllers utilizing intelligent devices, intelligent process I/O hardware, terminations and signal conditioning as require
- Process communication among drops of the system (process controllers, operator and software development stations) will use a mission critical redundant network. Variables are updated a minimum of once per second, with the capability of updating critical variables every 1/10 second and sequence of events recorder points with a 1 millisecond scan rate. The network will be based on an industry-standard, open-protocol capable of easily incorporating third-party products.
- Unit control PLCs will be integrated seamlessly with the process control and information management system. Combinations of controllers and PLCs will be dictated by the specific application being implemented. The appropriate seamless, transparent PLC integration is achieved on a wide variety of equipment and processes requiring logic control.
- Integrated overall vibration monitoring for start-up, coastdown and production state monitoring integrated with the PCS.
- Additional elements or programs, such as historical data storage and report generation, as may be required based on application requirements.
- Interfaces to a variety of Local Area Networks (LAN's) and Wide Area Networks (WANs) running a variety of Windows-based network software. Interfaces will be through required network security devices and interfaces.

The PCS will control in the system controller or intelligent field device. The system shall consist of a host controller capable of interfacing with local analog and discrete I/O, FOUNDATION fieldbus registered H1 devices, HART¹ capable smart devices, and Device Busses such as Profibus and DeviceNet.

The control system will be capable of performing coordinated modulating control and sequential logic in all power plant process areas, including but not limited to turbine controls, injection well control, H₂S abatement controls, electrical system controls, switch yard remote controls and balance of plant controls.

3.2 Pressure Instruments

In general, pressure instruments will have linear scales with units of measurement in pounds per square inch, gauge (psig). Pressure gauges will have either a blowout disk or a blowout back and an acrylic or shatterproof glass face. Pressure gauges on process piping will be resistant to plant atmosphere. Siphons will be installed on pressure gauges in steam service as required by the system design. Steam pressure-sensing transmitters or gauges mounted above the steam line will be protected by a loop seal.

Pressure test points will have isolation valves and caps or plugs. Pressure devices on pulsating services will have pulsation dampers.

3.3 Temperature Instruments

In general, temperature instruments will have scales with temperature units in degrees Fahrenheit. Exceptions to this are electrical machinery resistance temperature detectors (RTDs) and transformer winding temperatures, which are in degrees Celsius.

Temperature elements will be protected by thermowells except when measuring gas or air temperatures at atmospheric pressure. Temperature test points will have thermowells and caps or plugs.

RTDs will be 100-ohm platinum, 3-wire type. The element will be spring-loaded, mounted in a thermowell, and connected to a cast iron head assembly. Other types of RTDs such as 10 ohm copper RTDs are not used due to the presence of hydrogen sulphide.

Thermocouples will be Type J or K dual-element, grounded, spring-loaded, for general service. Materials of construction will be dictated by service temperatures. Thermocouple heads will be the cast type with an internal grounding screw.

3.4 Level Instruments

Reflex-glass or magnetic level gauges will be used. Level gauges for high-pressure service will have suitable personnel protection.

Gauge glasses used in conjunction with level instruments will cover a range that includes the highest and lowest trip/alarm set points.

3.5 Flow Instruments

Flow transmitters for general use will be the differential pressure-type with the range similar to that of the primary element. In general, linear scales will be used for flow indication and recording. In addition as appropriate for service use of magnetic Coriolis effect and Pitot tubes such as Annubar will be used.

3.6 Control Valves

Control valves in throttling service will generally be the globe-body cage type with body materials, pressure rating, and valve trims suitable for the service involve. Other style valve bodies (e.g., butterfly, eccentric disk) will be specified as appropriate for the intended service.

Valves will be designed to fail in a safe position.

Control valve body size will not be more than two sizes smaller than line size, unless the smaller size is specifically reviewed for stresses in the piping.

Control valves in 600-Class service and below will be flanged where economical. Where flanged valves are used, minimum flange rating will be ANSI 300 Class.

Critical service valves will be defined as ANSI 900 Class and higher in valves of sizes larger than 2 inches.

Severe service valves will be defined as valves requiring anticavitation trim, low noise trim, or flashing service, with differential pressures greater than 100 pounds per square inch (psi).

Valve actuators will use positioners and the highest pressure, smallest size actuator, and will be the pneumatic-spring diaphragm or piston type. Actuators will be sized to shutoff against at least 110 percent of the maximum shutoff pressure and designed to function with instrument air pressure ranging from 80 to 125 psig.

Motor operated valves are equipped with a non-relaxing gear train and nonrotating handwheel during electric operation. A minimum of eight independently set limit switches are provided on each valve.

Handwheels will be furnished only on those valves that can be manually set and controlled during system operation (to maintain plant operation) and do not have manual bypasses.

Control valve accessories, excluding controllers, will be mounted on the valve actuator unless severe vibration is expected.

Solenoid valves supplied with the control valves will have Class H coils. The coil enclosure will normally be a minimum of NEMA 4 but will be suitable for the area of installation. Terminations will typically be by pigtail wires.

Valve position feedback (with input to the DCS for display) will be provided for all control valves.

3.7 Instrument Tubing and Installation

Tubing used to connect instruments to the process line will be stainless steel for primary instruments and sampling systems.

Instrument tubing fittings will be the compression type. One manufacturer will be selected for use and will be standardized as much as practical throughout the plant.

Differential pressure (flow) instruments will be fitted with five-valve manifolds; two-valve manifolds will be specified for other instruments as appropriate.

Instrument installation will be designed to correctly sense the process variable. Taps on process lines will be located so that sensing lines do not trap air in liquid service or liquid in gas service. Taps on process lines will be fitted with a shutoff (root or gauge valve) close to the process line. Root and gauge valves will be main-line class valves.

Instrument tubing will be supported in both horizontal and vertical runs as necessary. Expansion loops will be provided in tubing runs subject to high temperatures. The instrument tubing support design will allow for movement of the main process line.

3.8 Pressure and Temperature Switches

Field-mounted pressure and temperature switches will have either NEMA Type 4 housings or housings suitable for the environment.

In general, switches will be applied such that the actuation point is within the center one-third of the instrument range.

3.9 Field-Mounted Instruments

Field-mounted instruments will be of a design suitable for the area in which they are located. They will be mounted in areas accessible for maintenance and relatively free of vibration and will not block walkways or prevent maintenance of other equipment.

Field-mounted instruments will be grouped on racks. Supports for individual instruments will be prefabricated, off-the-shelf, 2-inch pipestand. Instrument racks and individual supports will be mounted to concrete floors, to platforms, or on support steel in locations not subject to excessive vibration.

Individual field instrument sensing lines will be sloped or pitched in such a manner and be of such length, routing, and configuration that signal response is not adversely affected.

Liquid level controllers will generally be the nonindicating, displacement-type with external cages.

3.10 Instrument Air System

Branch headers will have a shutoff valve at the takeoff from the main header. The branch headers will be sized for the air usage of the instruments served, but will be no smaller than 3/8 inch. Each instrument air user will have a shutoff valve, filter, outlet gauge, and regulator at the instrument

Electrical Engineering Design Criteria

APPENDIX C.5 Electrical Engineering Design Criteria

1 INTRODUCTION

Project design, engineering, procurement, and construction activities will be controlled in accordance with various predetermined standard practices and project-specific programs/practices. An orderly sequence of events for project implementation is planned, consisting of the following major activities:

- Conceptual design
- Licensing and permitting
- Detailed design
- Procurement
- Construction and construction management
- Checkout, testing, and startup
- Project completion

This appendix summarizes the codes and standards, standard design criteria, and industrial good practices that will be used during the project. The general electrical design criteria defined herein form the basis of the design for project electrical components and systems. More-specific design information will be developed during detailed design to support equipment and erection specifications. It is not the intent of this appendix to present the detailed design information for each component and system, but rather to summarize the codes, standards, and general criteria that will be used.

Section 2 summarizes the applicable codes and standards, and Section 3 includes the general design criteria for motors, power and control wiring, protective relaying, classification of hazardous areas, grounding, lighting, heat tracing, lightning protection, raceway and conduit, and cathodic protection.

2 DESIGN CODES AND STANDARDS

Work will be designed and specified in accordance with applicable laws and regulations of the Federal Government and the State of California and applicable local codes and ordinances.

The latest version of the following general codes and industry standards will be used in design and construction:

- Antifriction Bearing Manufacturers Association (AFBMA)
- American National Standards Institute (ANSI)
- American Society for Testing and Materials (ASTM)
- Insulated Cable Engineers Association (ICEA)
- Institute of Electrical and Electronics Engineers (IEEE)
- Illuminating Engineering Society (IES)
- National Electrical Code (NEC) 2008
- National Electrical Manufacturers Association (NEMA)
- National Electrical Safety Code (NESC) 2007
- National Fire Protection Association (NFPA)
- Occupational Safety and Health Act (OSHA)
- Underwriters' Laboratories Inc. (UL)

In addition to these general codes and standards, the following specific standards will be used:

- Batteries

IEEE 450	Recommended Practice for Maintenance, Testing and Replacement of Large lead Storage Batteries
IEEE 484	Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations

- Battery Chargers

NEMA AB-1	Molded Case Circuit Breakers
NEMA PE-5	Electric Utility Type Battery Chargers

- Cable: Low Voltage
Power, Control and
Instrument

ASTM B 3	Standard Specification for Soft or Annealed Copper Wire
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ASTM B 8	Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-hard, or Soft
ASTM B 33	Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes
ASTM B 496	Standard Specification for Compact Round Concentric-Lay Standard Copper Conductors
ICEA S-66-524 (NEMA WC 7)	Cross-Linked-Thermosetting-Polyethylene-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
ICEA S-68-516 (NEMA WC 8)	Ethylene-Propylene-Rubber-Insulated Wire and Cable for the transmission and Distribution of Electrical Energy
ICEA S-73-532 (NEMA WC 57)	Standard for Control Cables
ICEA S-82-552 (NEMA WC 55)	Instrumentation Cables and Thermocouple Wires
IEEE-1202	Standard for Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies
NEC	National Electrical Code, NFPA 70
NEMA WC 26	Wire and Cable Packaging
<ul style="list-style-type: none"> • Cable Medium Voltage Power 	
ASTM B 3	Standard Specification for Soft or Annealed Copper Wire
ASTM B 8	Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
ASTM B 33	Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes
ASTM B 496	Standard Specification for Compact Round Concentric-Lay-Stranded Copper Conductors

ICEA S-66-524 (NEMA WC 7)	Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
ICEA S-68-516 (NEMA WC 8)	Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
IEEE-1202	Standard for Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies
NEC	National Electrical Code, NFPA 70
NEMA WC 26	Wire and Cable Packaging
UL 1072	Standard for Medium-Voltage Power Cables

- Cable Tray

NEMA VE-1	Cable Tray Systems
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- Cathodic Protection Equipment

ANSI B1.1	Unified Inch Screw Threads
ANSI B2.1	Pipe Threads
ASTM A 518	Corrosion-Resistant High Silicon Cast Iron
ASTM B 418	Cast and Wrought Galvanic Zinc Anodes for use in Saline Electrolytes

- Circuit Breakers, High Voltage

ANSI/IEEE C37.04	Rating Structure for AC High Voltage Circuit Breakers rated on a Symmetrical Current Basis
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ANSI C37.06	Preferred Ratings and Related Required Capabilities for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
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ANSI/IEEE C37.09	High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
ANSI/IEEE C37.010	Application Guide for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
ANSI C37.11	Requirements for Electrical Control for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis and a Total Current Basis

- Conduit

UL 6, ANSI C80.1	Rigid Steel Conduit
UL 797, ANSI C80.3	Electrical Metallic Tubing
UL 514, ANSI C80.4	All Fittings
UL 886	Hazardous Area Fittings
UL 360	Flexible Liquid-tight Conduit
NEMA TC6	PVC and ABS Plastic Utilities Duct and Underground Installation
NEMA TC9	Fittings for ABS and PVC Plastic Utilities for Duct for Underground Installation
UL 651	Electrical Rigid Nonmetallic Conduit
NEMA TC2, UL 514	Fittings for Electrical Rigid Nonmetallic Conduit

- Distribution Panels

ANSI C97.1	Low Voltage Cartridge Fuses, 600 volts or less
NEMA AB-1	Molded Case Circuit Breakers
NEMA PB-1	Panelboards
UL 50	Electrical Cabinets and Boxes

UL 67	Panelboards
NEMA ICS	Industrial Controls and Systems
NEMA KSI	Enclosed Switches
<ul style="list-style-type: none"> • Grounding Cable 	
ASTM B8	Specifications for Concentric-Lay Stranded Copper Conductors
<ul style="list-style-type: none"> • Grounding Connectors and Accessories 	
NEMA CC-1	Electrical Power Connectors for Substations
<ul style="list-style-type: none"> • Lighting Fixtures 	
NEMA FA-1	Outdoor Floodlighting Equipment
NEMA LE-1	Fluorescent Luminaries
UL 57	Standard for Safety, Electric Lighting Fixtures
UL 844	Standard for Safety, Electric Lighting Fixtures for Use in Hazardous Locations
UL 924	Standard for Safety, Emergency Lighting Equipment
<ul style="list-style-type: none"> • Lightning Arresters 	
ANSI/IEEE C62.11	Standard for Metal-Oxide Surge Arresters for AC Power Circuits
<ul style="list-style-type: none"> • Secondary Unit Substations 	

ANSI C37.13	Low-Voltage AC Power Circuit Breakers Used in Enclosures
ANSI C37.16	Preferred Ratings, Related Requirements, and Application Recommendations for Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors
ANSI/IEEE C37.20.1	Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear
ANSI/IEEE C37.20.2	Standard for Metal-Clad and Station -Type Cubicle Switchgear
ANSI C37.50	Test Procedures for Low-Voltage AC Power Circuit Breakers used in Enclosures
ANSI C37.51	Conformance Testing of Metal-Enclosed Low-Voltage AC Power Circuit Breaker Switchgear Assemblies
ANSI C57.12.00	General Requirements for Distribution, Power and Regulation Transformers
ANSI/IEEE C57.12.01	General Requirements for Dry-Type Distribution and Power Transformers
ANSI/IEEE C57.12.90	Test Code for Liquid Immersed Distribution and Power, and regulating Transformers
ANSI/IEEE C57.12.91	Test Code for Dry-Type Distribution and Power Transformers
<ul style="list-style-type: none"> • Metal-Clad Switchgear and Nonsegregated Phase Bus 	
ANSI A58.1	Minimum Design Load in Buildings and Other Structures
ANSI C37.04	Rating Structure for AC High-Voltage Circuit Breakers on a Symmetrical Current Basis
ANSI C37.06	Preferred Ratings and Related Required Capabilities for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

ANSI C37.20	Switchgear Assemblies Including Metal-Enclosed Bus
ANSI C37.23	Guide for Metal-Enclosed Bus and Calculating Losses in Isolated-Phase Bus
ANSI C57.13	Requirements for Instrument Transformers

- Motor Control Centers

NEMA ST-20	Dry-Type Transformers for NEMA General purpose Applications
NEMA AB-1	Molded Case Circuit Breakers
NEMA ICS-1	General standards for Industrial Controls and Systems
NEMA ICS-2	Industrial Control Devices, Controllers and Assemblies
UL 489	Molded Case Circuit Breakers and Circuit Breaker Enclosures
UL 508	Industrial Control Equipment
UL 845	Motor Control Centers

- Motors, Low Voltage

NEMA MG-1	Motors and Generators
AFBMA 9/ANSI B3.15	Antifriction Bearing Manufacturers Association
NEMA MG-2 APBMA 11/ANSI B3.16	Safety Standard for Construction and Guide for Selection, Installation and Use of Electrical motors and Generators
NEMA MG-13	Frame Assignment for Alternating Current Integral Horsepower Induction Motors

- Motors, Medium Voltage

ANSI/IEEE C50.41	Polyphase Induction Motors for Electric Power Generating Stations
IEEE 112	Test Procedure for Polyphase Induction Motors and Generators
NEMA MG-1	Motors and Generators
NEMA MG-2	Safety Standard for Construction and Guide for Selection, Installation, and Use of Electrical Motors and Generators
<ul style="list-style-type: none"> • Neutral Grounding Resistors 	
ANSI C76.1	Requirements and Test Costs for Outdoor Apparatus Bushings
IEEE 32	Requirements, Terminology, and Test Procedures for Neutral Grounding Devices
<ul style="list-style-type: none"> • Relay Panels 	
ANSI C37.20	Switchgear Assemblies Including Metal-Enclosed Bus
ANSI C37.90	Relays and Relay Systems Associated with Electric power Apparatus
<ul style="list-style-type: none"> • Transformers, Dry-Type 	
ANSI U1	General Requirements for Dry-Type Distribution and Power Transformers
NEMA ST-20	Dry-Type transformers for General Application
UL 506	Standard for Safety, Specialty transformers

Other recognized standards will be used as required to serve as design, fabrication, and construction guidelines when not in conflict with the above-listed standards.

The codes and industry standards used for design, fabrication, and construction will be the codes and industry standards, including all addenda, in effect as stated in equipment and construction purchase or contract documents.

3 ELECTRICAL DESIGN CRITERIA

3.1 Electric Motors

3.1.1 General Motor Design Criteria

These paragraphs outline basic motor design guide parameters for selecting and purchasing electric motors. The following design parameters will be considered:

- Motor manufacturer
- Environment, including special enclosure requirements
- Voltage, frequency, and phases
- Running and starting requirements and limitations and duty cycle
- Motor type (synchronous, induction, dc, etc.) and construction
- Power factor
- Motor Efficiency
- Service factor
- Speed and direction of rotation
- Insulation
- Oil lubrication systems
- Bearing construction, rating life of rolling elements, and external lube oil system for sleeve or plate bearings
- Ambient noise level and noise level for motor and driven equipment
- Temperature detectors
- Termination provisions for power, grounding, and accessories
- Installation, testing, and maintenance requirements
- Special features (shaft grounding, temperature and vibration monitoring, surge protection, etc.)
- Motor space heater requirements

3.1.1.1 Safety Considerations for Motors

The Occupational Safety and Health Administration rules will be followed for personnel protection. Belt guards will be specified for personnel safety and, when required, to prevent foreign objects from contacting belt surfaces. Guard screens will be provided over motor enclosure openings to prevent direct access to rotating parts. Electrical motors will be adequately grounded.

Motors in hazardous areas will conform to applicable regulatory requirements and will be UL labeled. Motor electrical connections will be terminated within oversized conduit boxes mounted to the motor frame.

3.1.1.2 Codes and Standards

Motors will be designed, manufactured, and tested in accordance with the latest applicable standards, codes, and technical definitions of ANSI, IEEE, NEMA, and AFBIVIA, as supplemented by requirements of the specifications.

3.1.1.3 Testing Requirements

Each type of ac and dc machine will be tested in accordance with the manufacturer's routine tests at the factory to determine that it is free from electrical or mechanical defects and to provide assurance that it meets specified requirements. The following criteria and tests will be used in testing each type of machine:

- Fractional horsepower, single-phase induction motors ($< 3/4$ hp)
- Test procedures will be in accordance with IEEE 114, Test Procedure for Single Phase Induction Motors.
- Integral horsepower, three-phase, 460 V induction motors ($3/4 - 250$ hp)
- Use routine tests listed in NEMA MG1 -12.51, Routine Tests for Polyphase Integral Horsepower Induction Motors.
- Test procedures will be in accordance with IEEE 112, Test Procedure for Polyphase Induction Motors and Generators.
- Induction motors rated above 600 V (251 hp)
- Routine tests listed in NEMA MG1-20.46, Polyphase Induction Motors for Power Generating Stations, will be performed on each motor.

The following additional tests and inspections will be performed on each motor larger than 1,500 hp. However, when duplicate motors are provided, perform the tests on one motor only.

- Locked-rotor current at fractional rated voltage
- Current balance
- Length of time of bearing test and final temperature rise of bearing
- A statement that bearings have been inspected and approved for shipment

- Insulation resistance-time curve and polarization index for motors with formed-coil stators
- Final value of motor noise levels, including statement that there is no objectionable single frequency noise
- Final air gap measurements (single air gap)
- Final value of the motor efficiency, power factor, and insulation resistance.

Motors that are specified to have complete tests performed on either the furnished motor or an electrically duplicate motor will require the following tests:

- Temperature
- Percent slip
- No-load saturation curve
- Locked-rotor saturation curve, including locked-rotor torque, current, and power
- Speed-torque and speed-current curves at rated voltage and at minimum starting voltage
- Efficiency at full, three-fourths, and one-half loads
- Power factor at full, three-fourths, and one-half loads
- Direct current motors

The following standard routine tests and inspections will be performed on each motor:

- High potential dielectric test
- Measurement of resistance of all windings
- Inspection of bearings and bearing lubrication system
- No-load running armature current, shunt field current, and speed in revolutions per minute, at rated voltage
- Full-load armature current, shut field current, and speed in revolutions per minute, at rated voltage

Test procedures will be in accordance with IEEE 113, Test Code for Direct Current Machines.

3.1.1.4 Electrical Design Criteria

Special requirements for individual motors and specifications for special application motors will be included in individual specification technical sections. The motor nameplate horsepower multiplied by the motor nameplate service factor will be at

least 15 percent greater than the driven equipment operating maximum brake horsepower. For motors with 1.15 service factor, the maximum load brake horsepower will not exceed the motor nameplate horsepower.

Emergency dc motors will operate continuously at the nominal system voltage with any supply voltage between 84 and 112 percent of the nominal 125 VDC system voltage.

Alternating current motors will be designed for full-voltage starting and frequent starting, where required, and will be suitable for continuous duty in the specified ambient conditions. Intermittent-duty motors will be selected where recognized and defined as standard by the equipment standards and codes.

The torque characteristics of induction motors will be as required to accelerate the inertia loads of the motor and driven equipment to full speed without damage to the motor or the equipment at any voltage from 90 to 110 percent of motor nameplate voltage, except those to be individually specified.

Temperature Considerations

Integral horsepower motors will be designed for an ambient temperature of 40° C.

Windings and Insulation

Insulated windings will have Class F nonhygroscopic insulation systems with Class B temperature rise and ambient temperature in accordance with NEMA MG1 standards.

Insulated stator winding conductors and wound-rotor motor secondary windings will be copper. The insulation resistance corrected to 40° C will be not less than motor rated kV +1 megohms for all windings. Where required, the windings will be treated with a resilient, abrasion-resistant material.

Overspeeds

Squirrel-cage and wound-rotor induction motors, except crane motors, will be so constructed that in an emergency of short duration they will withstand, without mechanical injury, overspeeds above synchronous speed in accordance with the

table in NEMA MG1- 12.48, Overspeeds for Motors.

Space Heaters

Space heaters will be sized as required to maintain the motor internal temperature above the dew point when the motor is not running. Motor space heaters will not cause winding temperatures to exceed rated limiting values or cause thermal protective device over-temperature indication when the motor is not energized.

In general, motors 1,000 hp or larger will have 240 V, single-phase, 60 Hz rated space heaters and will be energized by a 120 V, single-phase 60 Hz system. All 4,000 V motors will have space heaters. Heaters will be located and insulated so that they do not damage motor components or finish. Space heater leads will be stranded copper cable with 600 V insulation and will include terminal connectors.

Nameplates

Motor nameplate data will conform to NEMA MG1-20.60 requirements. The following additional nameplate data will be included for 4,000 V rated motors:

- Manufacturer's identification number
- Frame size Dumber
- Insulation system class designation
- Maximum ambient temperature for which the motor is designed or the temperature rise by resistance
- Service factor
- Starting limitations
- Direction of rotation and voltage sequence
- AFBMA bearing identification number for motors furnished with rolling element bearings
- Type and grade of bearing lubricant, attached adjacent to lubricant filling devices.
- For motors with connections to an external lubricant re-circulating system or with an integral forced lubrication system, oil pressure and oil flow required
- For dual voltage rated or multi-speed motors, connection diagram for the specified voltage or the specified speeds.

- For motors designed for service in hazardous areas:
 - Location class and group designation
 - Maximum operating temperature value or operating temperature code number

Environment

Location of individual motors within the plant will determine ambient temperature, corrosive environment, hazardous environment, and humidity to be experienced by the motors. These conditions will be considered in the purchase specification.

3.1.2 4,000 Volt Squirrel-Cage Induction Motors

3.1.2.1 Design and Construction

Design and construction of 4,000 V motors will be coordinated with the driven equipment requirements.

Motor power lead terminal housings will be adequately sized to terminate the power conductors. For 4,000 V motors, the power lead terminal housing will also be large enough to provide working space for field fabrication of stress cones within the housing and to contain the stress cones after installation.

Separate terminal housings will be provided for:

- Motor power leads
- Motor accessory leads
- Motor temperature detector leads

Leads will be wired into their respective terminal housings. Motor leads and their terminals will be permanently marked in accordance with the requirements of NEMA MG1, Part 2. Each lead marking will be visible after the terminals are taped.

Motors designed to rotate in only one direction will have the direction of rotation marked by an arrow mounted visibly on the stator frame near the terminal housings or on the nameplate and the leads marked for phase sequence T1, T2, T3 to correspond

to the direction of rotation and supply voltage sequence.

Outdoor motors will be TEFC with NEMA waterproof features or NEMA WPM
Indoor motors in wet areas will have outdoor motor features.

Exposed metal surfaces of motors for outdoor service will be protected with a corrosion-resistant coating.

3.1.2.2 Insulation

All motors shall be furnished with Class F or Class H insulation systems, provided the temperature rise is based on Class B maximum. An insulation resistance time curve corrected to 40°C for determining the polarization index for motor stator windings will be taken immediately before making the final high potential ground test. Each stator phase will be tested separately to ground, with other phases grounded. Motors will be tested at not less than 5,000 VDC. The ambient temperature, winding temperature, and relative humidity values will be included with the recorded data. The polarization index will not be less than 3.0. An insulation-to-ground dielectric test will be made on the motor windings at a value of two times rated voltage + 1,000.

3.1.2.3 Bearings

Horizontal motors, except motors for belted drives, will have split sleeve bearings of oil ring type, unless required otherwise.

Sleeve bearings on horizontal motors will be designed and located centrally with respect to running magnetic center to prevent the rotor axial thrust from being continuously applied against either end of the bearing. The motors will be able to withstand without damage the axial thrusts developed when the motor is energized. When sleeve bearings are not specified, horizontal motors will have antifriction bearings.

Thrust bearings for vertical motors will be able to operate for extended periods of time at any of the thrust loadings imposed by the specific piece of driven equipment during starting and normal operation, without damage to the bearings, the motor

frame, or other motor parts.

Motors with spherical roller thrust bearings will also have ball or roller guide hearings. Bearing lubricants will contain a corrosion inhibitor. The type and grade of lubricant will be indicated on a nameplate attachment to the motor frame or end shield adjacent to the lubricant filling device. Insulation will be provided on bearing temperature detectors and on oil piping connections when required to prevent circulation of shaft current through hearings. Bearings and bearing housings will be designed to permit disassembly in the field for bearing inspection or rotor removal.

3.1.2.4 Bearing Temperature Detectors

Thermocouple bearing temperature detectors complete with detector head and holder assemblies as required, will be furnished. Thermocouple lead wire insulation will be color-coded with standard colors to represent the thermocouple metals.

3.1.2.5 Winding Temperature Detectors

Winding temperature detectors will be furnished, installed, and wired complete. Temperature detectors will normally be three-wire resistance platinum temperature detectors (RTDs).

3.1.2.6 Temperature Detector and Terminal Block Requirements

Temperature detectors will be ungrounded, with detector leads wired to terminal blocks furnished in the accessory terminal housings. A grounding terminal for each temperature detector will be included with the detector lead terminals. The grounding terminals will be wired internally to a common ground connection in each terminal box. The internal wiring will be removable.

3.1.3 460 Volt Integral Horsepower Motors

3.1.3.1 Design and Construction

Design and construction of each 460 V integral hp motor will be coordinated with the

driven equipment requirements and the requirements of NEMA MG1 standards. Motors for service in hazardous areas will be individually considered as to type of enclosure, depending on the classification, group, and division of the hazardous area in question.

Exposed metal surfaces of motors for outdoor service will be protected with a corrosion-resistant coating.

Motor power lead terminal housing will be sized to allow for ease in terminating the incoming power cable. Space heater leads will also be routed into this terminal housing.

3.1.3.2 Bearings

Horizontal motors will have oil or grease-lubricated sleeve or antifriction bearings, unless otherwise required.

Bearings on horizontal motors will be designed and located centrally with respect to the running magnetic center, to prevent the rotor axial thrust from being continuously applied against either end of the bearings. The motors will be able to withstand without damage the axial thrusts developed when the motor is energized.

Vertical motors with spherical roller thrust bearings will also have ball or roller guide bearings. Thrust bearings for vertical motors will be able to operate for extended periods of time at any of the thrust loadings imposed by the specific piece of driven equipment during starting and normal operation without damage to the bearing, the motor frame, or other motor parts.

Bearings and bearing housings will be designed to permit disassembly in the field for bearing inspection or rotor removal.

3.1.4 Direct Current Machines

3.1.4.1 Design and Construction.

Direct current machines will be designed and constructed for continuous operation

and in accordance with NEMA MG1. Direct current motors rated at 120 V will be capable of accelerating their loads and operating continuously through a voltage range of 105 to 140 VDC.

3.1.4.2 Service Factor

For motors furnished with a service factor greater than 1.0, the motor nameplate will indicate the horsepower rating at 1.0 service factor and the service factor. The motor will be designed to provide a continuous horsepower capacity equal to the rated horsepower at 1.0 service factor without exceeding the total limiting temperature rise stated in these specifications for the insulation system and enclosure specified.

3.1.4.3 Insulation and Windings.

Insulated windings will have a minimum of Class B nonhygroscopic, or acceptable equivalent, sealed insulation system. Insulated winding conductors will be copper.

3.1.4.4 Armatures and Brushes

Commutator bars will be fabricated of silver-bearing copper and will be free of cracks, pits, slivers, and similar imperfections. Bars will be insulated with mica segments, assembled and seasoned as a unit, properly undercut, and securely mounted on the shaft. The area behind the armature commutator risers will be packed with an epoxy compound and cured. Coil end connections to the risers will be either soldered with high temperature, pure tin solder; brazed; or tungsten inert-gas welded.

Brush holders will be fabricated of nonferrous materials, located accurately, and mounted securely to position the brushes on the armature. Brush holder pockets will be sized to permit proper movement of the brushes. Means for adjusting brush pressures and brush assembly ring will be provided. A stop device will be furnished to prevent the brush terminal from scoring the commutator.

Brushes will be carbon, with insulated shunts sized for the rated brush current. Successful commutation in accordance with NEMA standards will be maintained over the load range encountered in service.

Openings will be provided for ease of inspection, pressure adjustment, and replacement of brushes, and for brush assembly ring adjustment.

3.1.4.5 Bearings

Sleeve bearings for horizontal motors will be oil-ring lubricated unless otherwise required. The oil ring will be one-piece construction.

3.1.5 Fractional Horsepower Motors

The type, design, and construction of each general, special, and definite purpose fractional horsepower motor will be coordinated with the driven equipment requirements and will be in accordance with the requirements of NEMA MG 1. Motors for service in hazardous areas will be individually considered for type of enclosure, depending on the classification, group, and division of the hazardous area in question.

Motors will be totally enclosed unless specified otherwise.

Exposed metal surfaces of motors for outdoor service will be protected, where practical, with a corrosion-resistant coating. Enclosure exterior and interior surfaces, air gap surfaces, and windings will be protected with a corrosion-resistant epoxy paint or coating.

Bearings will be self-lubricating and will be designed to operate in any position or at any angle.

3.1.6 Motor Operators for Nonmodulating Valve, Gate, or Damper Service

The following requirements are applicable to electric operators required for nonmodulating motor operators.

3.1.6.1 Rating, Design, and Construction

Motors will be designed for high torque, reversing service in a 40° C ambient temperature. Motors will have Class B or higher nonhygroscopic standard insulation.

plus two coats of epoxy resin. Requirements of NEMA MG1 and MG2 will apply.

Motors will be rated 460 V, three-phase, 60 Hz, unless otherwise indicated. The dc motors will be rated 120 VDC to operate from a nominal 125 V battery.

The motor time duty rating for normal opening and closing service will be not less than whichever of the following is greater:

- As required for three successive open-close operations
- As required for the service
- Not less than 15 minutes

Sufficient torque will be provided to operate against system torque at 90 percent nominal voltage for ac motors and at 84 percent nominal voltage for dc motors.

Motors will be totally enclosed unless specified otherwise.

Motors for service in hazardous areas will be individually considered for type of enclosure, depending on the classification, group, and division of the hazardous area in question.

3.1.6.2 Bearings

Double-shielded, grease-prelubricated, antifriction bearings will be furnished where commercially available. Motor leads will be terminated in the limit switch compartment.

3.1.6.3 Space Heaters

Motor operators will have 240 V rated space heaters energized at 120 VAC. Space heater leads will be terminated in the limit switch compartment.

3.2 Power and Control Wiring

3.2.1 Design Conditions

In general, all cables shall be UL listed, conductors will be insulated on the basis of a normal maximum conductor temperature of 90° C in 40° C ambient air, with a maximum emergency overload temperature of 130° C and a short-circuit temperature of 250° C. In areas with higher ambient temperatures, larger conductors will be used or higher temperature rated insulation will be selected. Conductor size and ampacity will be coordinated with circuit protective devices. Cable feeders from 4.16 kV switchgear to power equipment will be sized so that a short-circuit fault at the terminals of the load will not result in damage to the cable before normal operation of fault interrupting device (breaker is tripped or fuse is melted).

Instrument cable will be shielded and twisted to minimize electrical noise interference as follows:

- Aluminum-polyester tape with 100 percent coverage and copper drain wire will be used for shielding.
- Low-level analog signal cables will be made up of twisted and shielded pairs.
- Except where specific reasons dictate otherwise, cable shields will be electrically continuous. When two lengths of shielded cable are connected together at a terminal block, a point on the terminal block will be used for connecting the shields.
- For multi-pair cables using individual pair shields, the shields will be isolated from each other. To be effective, instrument cable shields will be grounded on one end as follows: The shields on grounded, as well as ungrounded, thermocouple circuits will be grounded at the thermocouple well.
- Multi-pair cables used with thermocouples will have individually isolated shields so that each shield will be maintained at the particular couple ground potential.
- Each resistance temperature detector (RTD) system will be a three-wire system consisting of one power supply and one or more **RTDs** and will be grounded at only one point.
- **RTDs** embedded in windings of transformers and rotating machines will be grounded at the frame of the respective equipment.
- The low or negative potential side of an instrument signal pair will be

grounded at the same point where the shield is grounded. Where a common power supply is used, the low side of each signal pair and its shield will typically be grounded at the power supply.

3.2.2 Conductors

3.2.2.1 Design Basis

Electrical conductors will be selected with an insulation level applicable to the system voltage for which they are used and ampacities suitable for the load being served. The type of cable used will be determined by individual circuit requirements and individual equipment manufacturer's recommendations.

3.2.2.2 Cable Ampacities

The maximum ampacities for any cable will be in accordance with the NEC. In addition to ampacity, special requirements such as voltage drop, fault current availability, temperature derated ampacity and environment will be taken into consideration when sizing cable.

3.2.3 Insulation

Cable insulation and construction will be as follows.

3.2.3.1 Flame Retardance

To minimize the damage that can be caused by a cable fire, cables will have insulations and jackets with nonpropagating and self-extinguishing characteristics. As a minimum, these cables will meet the flame test requirements of IEEE 383, using a gas-burner flame source. These characteristics are essential for cables installed in electrical cable tray in the plant.

3.2.3.2 Medium Voltage Power Cable

Power cable with minimum 5 kV class and 133% insulation level will supply all 4.16 kV service and will be routed in trays, conduits, or underground duct banks.

3.2.3.3 Low Voltage Power Cable, 600 Volts

Power cable with 600V class insulation will supply power to loads at voltage levels of 480 VAC and below and 125 VAC and below. Cables will be routed in trays, conduits, or ducts. All cables shall meet or exceed flame test requirements of IEEE 1202

3.2.3.4 Control Cable, 600 Volts

Nonshielded control cable with 600 V class insulation will be used for control, metering, and relaying. Cables will be routed in trays, conduits, or ducts. Cable shall be capable of storage, handling, bending, and installation at ambient temperatures as low as -7 degree C without cracking the jacket or insulation.

3.2.3.5 Instrument Cable, 300 or 600 Volts

Instrument cable will be used for control and instrument circuits that require shielding to avoid induced currents and voltages. Cable shall be capable of storage, handling, bending, and installation at ambient temperatures as low as -7 degree C without cracking the jacket or insulation.

3.2.3.6 Thermocouple Extension Cable

Thermocouple extension cable will be used for extension leads from thermocouples to junction boxes and to instruments for temperature measurements. Cables will be routed in trays or conduits. The cable jacket shall be UL listed type PLTC in accordance with NEC.

3.2.3.7 High Temperature Cable

High temperature cable will be used for wiring to devices located in areas with ambient temperatures normally above 75° C. Cables will be routed in conduit. Cable lengths will be minimized by terminating the cable at terminal boxes or conduit outlet fittings located outside the high temperature area and continuing the circuit with control or thermocouple extension cable.

3.2.3.8 Lighting and Fixture Cable

Lighting and fixture cable designations and conductor sizes will be identified on the drawings. The wire used for interior lighting and receptacles will be copper 600 V, 75-degree type THWN insulation or equal.

3.2.3.9 Grounding Cable

Grounding cable will be insulated or un-insulated bare copper conductor sized as required.

3.2.3.10 Switchboard and Panel Cable

Switchboard and panel cable will be insulated to 600 V. Cable will be NEC Type SIS or XHHW-2, meeting the LTL VW-1 flame test.

3.2.3.11 Special Cable

Special cable will include cable supplied with equipment, prefabricated cable, coaxial cable, communication cable, etc. This cable will normally be supplied by a particular manufacturer. Special cable will be routed in accordance with the manufacturer's recommendations.

3.2.3.12 Miscellaneous Cable

If other types and constructions of cable are required as design and construction of the unit progress, they will be designated and routed as required.

3.2.4 Testing Requirements_

Preoperational tests will be performed on insulated conductors after installation, as follows:

- Insulated conductors with insulation rated 5,000 V and above will be given a field dc insulation test as specified in Part 6 of 10EA Standards S-68-516 and S-66-524. All cables shall meet or exceed the flame test requirements per IEEE 383 (for size 1/0AWG and larger) and 1202(CSA-FT4) (for size 250MCM and larger).

- Low-voltage cables will be either insulation-resistance tested before connecting to equipment or functionally tested (at equipment operation voltage) as part of the checkout of the equipment system. All cables will pass the IEEE Vertical Tray Flame Test or the ICEA T-29-520 210,000 BTU/HR flame test.
- Insulated conductors will be continuity-tested for correct conductor identification.

3.2.5 Installation

Cable installation will be in accordance with the following general rules:

- Cables will be routed as indicated in the circuit raceway schedule
- Cable pulling tension will not exceed the maximum tension recommended by the cable manufacturer, and the pulling tension in pounds at a bend will not exceed the cable manufacturer's recommendations for sidewall pressure. Minimum bend radii will not exceed the manufacturer's recommendations.
- Cable will be exercised to prevent tension and bending conditions in violation of the manufacturer's recommendations.
- Cable supports and securing devices will have bearing surfaces located parallel to the surfaces of the cable sheath and will be installed to provide adequate support without cutting or deforming the cable jackets or insulation.
- Nylon ties will be used to lace together conductors entering panelboards, control panels, and similar locations after the conductors have emerged from their supporting raceway and before they are attached to terminals.
- Both ends of circuits will be identified.
- Spare conductors of a multiconductor cable will be left at their maximum length for possible replacement of any other conductor in the cable.
- Cables will be installed in accordance with manufacturer's requirements and recommendations.

3.2.6 Connectors

This subsection defines methods of connecting cable between electrical systems and equipment. In this subsection, the term "connector" is applied to devices that join two or more conductors or are used to terminate conductors at equipment terminals to provide a continuous electrical path.

Connector material will be compatible with the conductor material to avoid the occurrence of electrolytic action between metals. Connectors will meet the bolt hole

requirements of Paragraph CO -4.05 of NEMA Standard Publication for Electric Power Connectors, Publication CC1.

Medium voltage cables will have stress cones at their terminations. Stress cones will be the preformed type suitable for the cable to which they are to be applied.

Power cables will not be spliced. Control and low-level instrument cable will be spliced only at pigtails and at the transition to high temperature wire. Connections will be made in conduit fittings or junction boxes, using terminal blocks or an appropriate connector.

3.3 Protective Relaying

The selection and application of protective relays are discussed in the following paragraphs. These relays protect equipment in the electrical transmission, generation, and distribution systems.

3.3.1 General Requirements

The following general requirements apply to all protective relay applications:

- The protective relaying scheme will be designed to remove or alarm any of the following abnormal occurrences:
 - Overcurrent
 - Undervoltage or overvoltage
 - Frequency variations
 - Overtemperature
 - Abnormal pressure
 - Open circuits and unbalanced current
 - Abnormal direction of power flow
- The protective relaying system will be a coordinated application of individual relays. For each monitored abnormal condition, there will exist a designated primary device to detect that condition. If possible, failure of any primary relay will result in the action of a secondary, overlapping scheme to detect the effect of the same abnormal occurrence. The secondary relay may be the primary relay for a different abnormal condition. Alternate relays may exist to detect the initial

abnormal condition but with an inherent time delay so that the alternate relays will operate after the primary and secondary relays. Similarly to secondary relays, the alternate relays may be primary relays for other abnormal conditions. Protective relays will be selected to coordinate with protective devices supplied by manufacturers of major items and the thermal limits of electrical equipment, such as transformers and motors.

- Secondary current produced by current transformers will be in the 0-5 A range, and voltage signals produced by voltage transformers will normally be 120 V.

3.3.2 Generator Protective Relays

Protective relay packages will be provided to minimize the effects of the following faults and malfunctions:

- Generator phase faults
- Generator stator ground faults
- Stator open circuits and unbalanced currents (negative sequence)
- Loss of excitation
- Backup protection for external system faults
- Reverse power
- Generator voltage transformer circuit monitoring
- Underfrequency/overfrequency
- Breaker failure

Equipment furnished with the generator's excitation equipment will provide the following additional protection:

- Underexcitation
- Overexcitation
- Generator field ground faults
- Excessive volts per hertz

Additional generator protective monitoring equipment will be provided to protect against the following:

- High bearing temperatures
- Overspeed conditions
- Excessive vibrations
- Generator overheating

- Loss of generator coolant
- High generator coolant temperature

A typical complement of protective relays for the turbine generator may be as follows. The actual protective relaying to be used will be similar and will be developed during design stages:

- Generator Differential Relay (Device 87-G) - This relay will provide primary generator protection against three-phase and phase-to-phase faults within the generator. This relay will not detect ground faults within its zone of protection.
- Generator Ground Relay (Device 64-G) - This will be a low voltage pickup, overvoltage relay that will sense voltage across the generator neutral grounding transformer secondary resistor when a ground fault occurs in the generator, generator phase bus duct, generator step-up transformer low voltage windings, or the surge protection and voltage transformer equipment.
- Negative Sequence Relay (Device 46) - This relay will protect against unbalanced phase currents resulting from unbalanced loading, unbalanced faults, a turn-to-turn winding fault, or an open circuit. Negative sequence currents exceeding the generator allowable limits will result in overheating of the generator rotor.
- Loss-of-Field Relay (Device 40) - This relay, complete with timer, will protect against thermal damage caused by underexcitation and loss of field. This relay will provide backup protection for excitation system protective devices furnished with the generator.
- Reverse Power Relay (Device 32) - This relay will protect the turbine generator by detecting generator reverse power flow or motoring. This relay will initiate a normal sequential shutdown.
- Voltage Balance Relay (Device 60) - This relay will monitor two voltage transformer circuits to the generator voltage regulator and protective relays. Upon loss of relaying potential, this relay will disable the loss-of-field relay to avoid false tripping of the unit. Upon loss of potential to the voltage regulator, the voltage balance relay will transfer the voltage regulator from the automatic to manual mode of operation. An alarm will be actuated upon loss of either potential.
- Underfrequency Relay (Device 81) - This relay will detect underfrequency conditions.
- Overvoltage Relay (Device 27) and Undervoltage Relay (Device 59) - The voltage regulators and excitation system will include interlocks and protective circuits to prevent operating the generator beyond its design limits. These relays will alarm if the voltage regulator fails to maintain voltage within design limits.
- Field Ground Fault. Protection Relay (Device 64F) - This relay will alarm grounds

on the generator field.

- Generator Backup Distance Relay (Device 21G) - This relay will provide backup protection against external system faults. This relay will operate only if an external system fault persists after all other primary system relays, including breaker failure, have failed to operate. This relay will trip the generator lockout relay.

3.3.3 Power Transformer Relays

3.3.3.1 Generator Transformer

The generator step-up transformer will be protected against the effects of the following conditions:

- Phase faults
- Ground faults
- Sudden pressure

This protection will be provided by the following relays:

- Differential Relay (Device 87-T) - This relay will provide transformer primary protection by detecting three-phase and phase-to-phase faults in the generator transformer low voltage delta-connected windings and three-phase, phase-to-phase, and phase-to-ground faults in the generator transformer high voltage wye-connected windings.
- Time Overcurrent Relay (Device 51-TN) - This relay will provide sensitive backup protection for ground faults in the external system.
- Sudden-Pressure Relay (Device 63-T) - This relay will detect a rapid increase in pressure within the transformer tank associated with an internal fault. This relay will be furnished with the transformer.

Loss of cooling and resulting high temperature will be alarmed.

3.3.3.2 Unit Auxiliary Transformers.

The unit auxiliary transformers will be protected against the effects of the following conditions:

- Phase faults
- Ground faults
- Sudden pressure

This protection will be provided by the following relays:

- Differential Relay (Device 87ST) - This relay will provide primary protection for the high voltage and low voltage windings of the unit auxiliary transformers and for the cable connecting each low voltage winding to each incoming main breaker in the plant metal-clad switchgear lineups. This relay offers protection against phase-to-phase and three-phase faults. Device 87ST is relatively insensitive to ground faults on the secondary side of the transformer should the fault current magnitudes be less than the maximum available ground fault current.

Overcurrent Relay (Device 51N) - This relay will be connected to the bushing current transformer on the neutral of the low voltage winding of the unit auxiliary transformer. This relay will also provide backup protection for ground faults in the transformer low voltage winding, in the cable, on the switchgear buses, or on feeders emanating from the switchgear lineups.

- Sudden-Pressure Relay (Device 63) - This relay will detect a rapid increase in pressure within the transformer tank associated with an internal fault. This relay will be furnished with the transformer.

3.3.4 Metal-Clad Switchgear

The protective relays used in the 4,160 V metal-clad switchgear lineups are discussed in the following paragraphs.

3.3.4.1 Incoming Breakers

Each incoming breaker will have time overcurrent relays (Device 51) and a time overcurrent ground detection relay (Device 51N). Device 51 will detect and trip the respective switchgear incoming breaker for sustained overloads and short-circuit currents on the switchgear bus. These relays will provide backup protection for faults on feeders emanating from the switchgear lineups. Device 51N will be residually connected to switchgear current transformers and provide primary protection for ground faults on the switchgear bus and backup protection for ground faults in feeders emanating from the switchgear lineup.

The medium voltage switchgear bus will have undervoltage relays (Device 27) or transducers to detect bus voltage drops to a preset level.

3.3.4.2 Low Voltage Load Center.

Each load center transformer will be protected by a 4.16 kV circuit breaker. Protection devices will include time overcurrent relays (Device 51), instantaneous current relays (Device 50), and ground fault relays (Device 51N), or a multifunction transformer protection relay.

3.3.4.3 Medium Voltage Motor Feeders

Each single-speed induction motor will be protected by main line fuses and a microprocessor motor protection/management relay (MPR). The MPR will provide primary equipment and cable time overcurrent, instantaneous overcurrent, open phase, and zero sequence protection.

3.3.5 480 Volt Load Center Switchgear_

The MCCs will be powered directly from the secondary of the load center transformer through a main secondary circuit breaker. Each magnetic starter within an MCC that supplies power to a motor will have an adjustable motor circuit protector and a thermal overload element in the starter.

3.3.5.1 480 Volt Motor Control Centers

MCCs will be protected by the 480 V switchgear feeder breakers, which have adjustable long-time and short-time SSTD elements for phase protection and ground fault protection in a manner similar to that described in Subsection 3.3.5. 480 Volt Load Center Switchgear. The SSTD will protect the MCC feeder circuit and the bus against sustained short-circuit currents and serve as backup protection for MCC feeder circuits.

Each magnetic starter within an MCC that supplies power to a motor will have an adjustable motor circuit protector and a thermal overload element in the starter.

Certain nonmotor loads will be fed from MCC feeder circuit breakers. The feeder breakers will be thermal-magnetic molded-case breakers sized to protect supply

cable and individual loads.

3.3.5.2 480 Volt Power Panels

Power panels will have thermal-magnetic circuit breakers sized to protect supply cable and individual loads.

3.4 Classification of Hazardous Area

Areas where flammable and combustible liquids, gases, and dusts are handled and stored will be classified for the purpose of determining the minimum criteria for design and installation of electrical equipment to minimize the possibility of ignition. The criteria for determining the appropriate classification are specified in NEC Article 500 (NFPA 70/ANSI C1).

In addition to defining hazardous areas by class and division, each hazardous element is also assigned a group classification (A, B, C, etc.). The group classifications of hazardous elements are specified in NEC Article 500 and NFPA Standard 497M.

Electrical equipment in areas classified as hazardous will be constructed and installed in accordance with NEC Articles 501 and 502.

References for use in classification of areas, as well as specification of requirements for electrical installation in such areas, include:

- NESC, ANSI C2
- NEC, ANSI C1. NFPA 70/ANSI C1
- NFC, NFPA

3.5 Grounding

The station grounding system will be in an interconnected network of bare copper conductor and copper-clad ground rods. The system will protect plant personnel and equipment from the hazards that can occur during power system faults and lightning strikes.

3.5.1 Design Basis

The station grounding grid will be designed for adequate capacity to dissipate energy from ground fault current under the most severe conditions, with grid

spacing such that safe voltage gradients are maintained. The system will be in accordance with IEEE 80, IEEE 142, and NEC, NFPA 70.

Bare conductors installed below grade will be spaced in a grid pattern to be indicated on the construction drawings. Each junction of the grid below grade will be bonded together.

Ground stingers will be brought through the ground floor and connected to the building steel and selected equipment. Also, the grounding system will be extended, by way of stingers and conductor installed in cable tray, to the remaining plant equipment.

Equipment grounds will conform to the following general guidelines:

- Grounding conductors will conform to NEC.
- Major equipment, such as switchgear, MCCs, relay panels, and control panels, will have integral ground buses that will be connected to the station ground grid.
- Electronic panels and equipment, where required, will be grounded using an insulated ground wire connected in accordance with the manufacturer's recommendations.
- Motor supply circuits to 460 V motors, which use four-conductor cable or three-conductor cable with a ground in the interstices, will use this ground for the motor ground. For 460 V motor supply circuits, which use three single-conductor cables, a separate ground conductor will be used.
- All 4,000 V motors will have a minimum of one 1/0 AWG bare copper ground conductor connected between the motor frame and the station ground grid.
- Single-conductor ground wires installed in conduit will be insulated.

3.5.2 Materials

Grounding materials will be as follows:

- Ground rods will be copper. Rod length and diameter will be determined by soil resistivity and subsurface mechanical properties. Where the required ground rod length exceeds 10 feet, standard sections will be connected together.
- Cable will be either soft-drawn copper with Class B stranding or copper-clad steel.
- Compression-type connectors that meet the requirements of IEEE 837 will be used for the buried connectors.
- Clamps, connectors, and other hardware used with the grounding system will be

- designed for that use and purchased from an approved supplier.
- Ground wires installed in conduit will be soft-drawn copper with Class B stranding and green-colored 600 V insulation. Ground wires larger than No. 6 AWG may be marked green in lieu of green-colored insulation.

3.6 Site Lighting

The site lighting system will provide personnel with illumination to perform general yard task, safety, and plant security. Power used to supply outdoor roadway and area lighting fixtures will be at 277 V.

3.6.1 Lighting Design Basis

The lighting system will be designed to provide illumination levels recommended by the following standards and organizations:

- IES RP-7 - Standard Practice for Industrial Lighting
- IES RP-8 - Standard Practice for Roadway Lighting
- IES RP-24 - Standard Practice for Lighting Offices Containing Computer Display Terminals

Light source size and fixture selections will be based on the applicability of the luminaries for the area under consideration during detail design.

3.6.2 Roadway and Area

Roadway and area lighting will be designed using high-pressure sodium light sources. The light fixtures will be the cutoff type designed to control and direct light within the property line of the facilities. Roadway light fixtures will be installed on hot-dip galvanized steel poles. Local task lighting will be installed on buildings or equipment.

3.6.3 Lighting Control

Electric power to outdoor light fixtures will be switched on and off with photoelectric controllers. Local task lighting will be controlled with photoelectric controllers and manual switches at the task.

3.7 Freeze Protection

A freeze protection system will be provided for outdoor equipment, as required.

Three-wire, self-regulating heating cable will be directly applied to pipe. These heating cable circuits can be assembled and installed in the field using the appropriate connection kits. Heating cable will withstand the maximum surface temperature of the pipe to which it is applied. Power distribution panelboards will furnish power to the freeze protection circuits. Power to the freeze protection circuits will be controlled by ambient thermostats; loss of power or broken cable will be alarmed.

3.8 Lightning Protection

Lightning protection will be provided, as required, for all structures.

Lightning protection will be provided for buildings and structures generally in accordance with NFPA 780 but will not be UL "Master" labeled.

The grounding system for lightning protection will be bonded to the plant main grounding system.

3.9 Raceway and Conduit

The design and specifications for the raceway and conduit systems used to support and protect electrical cable will be in accordance with NEC provisions.

3.9.1 Cable Tray

Cable trays will be the trough or ladder type with a maximum rung spacing of 9 in., nominal depths of 4 to 6 in., and various widths as required. Horizontal trays will have a maximum spacing of 20 ft between cable tray supports; vertical trays, 8 ft.

Fittings (elbows, tees, etc.) will be supported in accordance with NEMA standards and will have a radius equal to or greater than the minimum bending radius of the cables they contain.

Electric systems such as special noise sensitive circuits and analog instrumentation circuits will have solid bottom trays.

For 4.16 kV power cables, the summation of the cross-sectional areas of cable in tray will be limited to 30 percent of the usable cross section of the tray. For 480 V power and control cables, the limit will be 40 percent. For instrument cable, the limit will be 50 percent.

The minimum design vertical spacing for trays will be 12 in., measured from the bottom of the upper tray to the top of the lower tray. At least a 9-in. clearance will be maintained between the top of a tray and beams, piping, or other obstacles to facilitate installation of cables in the tray. A working space of not less than 24 in. will be maintained on at least one side of each tray.

Vertical trays will have covers that allow ventilation. Solid bottom tray and outdoor tray will have solid covers. The top tray of horizontal tray runs located under floor grating will also have solid covers. All outside cable tray will be covered.

3.9.2 Conduit

Conduit will be used to protect conductors routed to individual devices, in hazardous areas, and where the quantity of cable does not economically justify the use of cable tray.

Electrical metallic tubing (EMT) will be used indoors in nonhazardous areas for lighting branch circuits and communication circuits.

PVC, EMT, and rigid galvanized steel conduit will be used for underground duct banks and some below grade, concrete-encased conduit.

Liquidtight, flexible metallic conduit will be used for connections to accessory devices such as solenoid valves, limit switches, pressure switches, etc.; for connections to motors or other vibrating equipment; and across areas where expansion or movement of the conduit is required.

Exposed conduit, unless specific environmental requirements dictate the use of plastic or aluminum conduit, will be rigid galvanized steel.

Exposed conduit will be routed parallel or perpendicular to dominant surfaces.

Conduit in finished areas, such as the offices and control room, will normally be concealed. Conduit will be routed at least 6 in. from the insulated surfaces of hot water, steam pipes, and other hot surfaces. Where conduit must be routed parallel to hot surfaces, high-temperature cable will be used.

Conduit will be sized in accordance with NEC requirements. Conduit will be securely supported within 3 ft of connections to boxes and cabinet.

3.9.3 Duct Bank and Manholes

Underground circuits will be installed in reinforced duct bank, unreinforced duct bank, or in direct buried conduit, as required by the final design.

Underground conduits will be rigid Schedule 40 PVC. Stub-ups will be made using rigid, galvanized steel conduit elbows and galvanized fittings as required.

Conduit runs installed below grade (except in floor slabs) will be encased in a minimum of 3 in. of concrete on all sides. The minimum spacing between conduits in underground duct banks will be 1-1/2 in. Reinforced concrete will be used in heavy traffic areas.

The top of concrete encasement for underground conduit will be a minimum of 24 in. below grade. Horizontal bends in underground conduits will be made using long radius sweeps.

Duct banks will slope downward toward manholes at a slope of 3 in. per 100 ft, minimum.

In paved areas, conduits will be stubbed up in a coupling flush with finished grade. In unpaved areas, conduits will be stubbed up in a coupling 6 in. above finished grade and will be encased.

As a minimum, 20 percent (or not less than one) spare conduits (2 in. minimum size) will be installed in underground duct banks, except for single- or double-conduit duct

banks for street lighting or to individual remotely located equipment.

In paved areas, spare conduits will be stubbed up in a coupling (with conduit plug) flush with finished grad. In unpaved areas, spare conduits will be stubbed up in a coupling (with conduit plug) 6 in. above finished grade and will be encased.

Reinforced concrete manholes and electrical vaults will be provided, where required, so that cable may be installed without exceeding allowable pulling tensions and cable sidewall pressures. Each manhole will have the following provisions:

- Provisions for attaching cable pulling devices
- Provisions for racking cables
- Manhole covers of sufficient size to loop-feed the largest diameter cable through the manhole without splicing

Conduit from manholes to the equipment at remote locations will be changed to rigid steel before emerging from below grad.

Duct bank and manholes will be designed in accordance with the seismic criteria defined in the Structural Design Criteria.

3.10 Cathodic Protection System

Buried carbon steel structures will be provided with cathodic protection because of the potential hazard should a leak develop. If the site's soil resistivity is less than 200 ohmmeter, then cathodic protection will be provided for all other buried structures. The cathodic protection system for steel structures will be either impressed current or sacrificial galvanic anode, depending on soil conditions and pipe size.